

JPRS-CEN-90-016  
21 DECEMBER 1990



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# ***JPRS Report***

# **Science & Technology**

***CHINA: Energy***

19980122 145

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NATIONAL TECHNICAL INFORMATION SERVICE  
SPRINGFIELD, VA. 22161

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# Science & Technology

## China: Energy

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### Status, Policy of New and Renewable Energy Development

916b0010B Chongqing XINNENGYUAN [NEW ENERGY SOURCES] in Chinese Vol 12, No 10, 5 Oct 90 pp 3-4

[Article by Gao Xikang [7559 6932 1660], Hu Chengchun [5170 2052 2504], and Lu Weide [7120 4850 1795], China Energy Resources Research Committee, Special Committee on New Energy Resources]

[Text]

#### Precis

China's conventional energy sources are in short supply. The rational and feasible way to alleviate energy shortages in rural and frontier areas is to use new and renewable energy sources. This article explains China's policies for the development of new and renewable energy sources, and summarizes the areas in which gains have been made.

#### Introduction

China is a developing country with a large population and a formerly weak industrial base. Forty years ago, China had already built independent coal, oil, and electric power industries, and by the end of 1989 had forged an annual production capability of 1.04 billion metric tons of coal, 137 million metric tons of oil, 14 billion cubic meters of natural gas, and 582 billion kWh of electric power. But in the last 10 years, China's energy supply requirements have grown more tense with each day. Especially in rural areas, where 80 percent of the population live and where firewood has been the main source of fuel, many small towns have in recent years become engaged in developing enterprises, and the consumption of energy is increasing greatly, to the point that now 30 percent of rural homes do not have electricity for domestic use.

The shortage of energy sources has also created ecological and environmental problems. Planting of trees cannot keep up with the felling of trees; In the last 50 years desert areas across the country have increased by 50,000 square kilometers. Now, production of crops and straw in the countryside is about 500 million tons, but fuel, feed, and industrial raw material requirements are at least 700 million tons. Because of this about 80 million households go 50 days without fuel.

#### Policies, General and Specific

In view of this state of affairs, the Chinese government has, as a general policy with respect to developing new and renewable energy sources in the rural and border areas, for a long time considered subsidizing energy sources. This is characterized as the "sixteen character policy": suit measures to local conditions, in mutual assistance be utmost, share utilities, be foremost in efficiency. At the same time, the government has applied a specific liberal policy toward industrialization and

commercialization of new and renewable energy resource products, and is offering such products of reliable quality and reasonable cost to rural and frontier areas.

#### Toil and Reward

China stresses self-reliance and a policy of developing new and renewable energy sources not affected by international oil price fluctuations.

Since the end of the seventies the Chinese government has attached great importance to the research and development of new and renewable energy sources. It has established over 20 special research institutes throughout the country, and has supported universities and enterprises in the effort. Now, there are 3,000 engineers and technicians working in this field. Up to 100 new energy source enterprises have been set up in various localities to produce solar energy collectors, solar batteries, and wind power electric generators. Concerned central ministries have joined with the localities in establishing several nationwide technology development centers and research and training centers to spread technical cooperation throughout China (such as the China Wind Power Technology Development Center, the China Bio-mass Energy Technology Development Center, China Photoelectricity Development Center, Remote Areas Small Hydroelectric Research and Training Center, Agricultural Energy Resource Research and Training Center, Chengdu Humidity Research and Training Center, and the Tianjin Geothermal Research and Training Center).

The development of new and renewable energy sources is manifested in the following ways: According to incomplete statistics, by the end of 1989 rural households throughout the country were using 46 million humidity collectors; small hydroelectric units for a total installed capacity of 124 million kW; 105,000 small wind powered electric generators which together with medium scale wind powered generators provide a total installed capacity of 15,000 kW; 1,600 windmill water pumps with a total power equivalency of 2,110 kW; 20,000 kW of geothermal generators; low-temperature geothermal energy used directly for heat amounts to approximately 380,000 kW of equivalent electric energy; 8,300 kW of tidal power generators; 1.5 million square meters of solar energy water heaters; 270,000 square meters of solar structures; 11,000 solar heated rooms; and 1,100 kW of installed solar batteries.

Bio-gas furnaces, bio-mass alcohol, sail power assisted navigation, and wave power generators are all being developed for use. Amorphous silicon solar batteries, bio-mass diesel oil, urban trash processors, wind power generated heat, new hydrogen technology and hydrogen storage technology are other items on which research has already begun.

### Energy Vice Minister Comments on New and Renewable Energy Sources

916b0010A Chongqing XINNENGYUAN (New Energy Sources) in Chinese Vol 12, No 10, 5 Oct 90 pp 2-3

[Abstract of speech by Lu Youmei [7120 0147 2812], Vice Minister of the Ministry of Energy Resources, at the opening of the International Conference on New and Renewable Energy Sources, Beijing 1990]

[text] Developing new energy sources is a common enterprise worldwide, something the world watches closely. On the occasion of the convening of this conference, as representative of China's Ministry of Energy Resources, I wish to extend hearty congratulations to the conference representatives, and to guests from the various countries, in-country specialists, scholars, and other representatives, I wish to extend a warm welcome and cordial greetings.

The mid-term strategy to develop China's energy industry is to realize by the year 2,000, in the primary energy category, a total volume of 1.43 billion metric tons of standard coal, of which the production volume of raw coal will be 1.4 billion metric tons (1 billion tons was the new high in 1989), 200 million tons of crude oil (137.6 million tons in 1989), 30 billion cubic meters of natural gas (14.4 billion cubic meters in 1989), from water power an energy equivalent of 90 million tons of standard coal, and from nuclear power an energy equivalent of 12 million tons of standard coal. And in the secondary energy category, 1.2 trillion kWh of energy (in 1989 it was 580 billion kWh), to include 225 billion kWh of hydroelectric power (105.5 billion kWh in 1989), and 30 billion kWh from nuclear power. By then, the relative volume of coal in the first energy category will have diminished some, and the proportion of electric power converted from coal will have increased (from a current 27 percent up to 33 percent). But, also by that time, the supply and consumption of energy relative to population, especially of electric power, oil, and natural gas will still be far below world standards.

China is faced with a great need to develop coal, oil, natural gas, nuclear energy, and electric power sources, and at the same time give special attention to developing new energy sources and renewable energy sources to supplement normal sources, and along with that improve the environment, protect against atmospheric pollution, in order to develop and provide even better energy sources for future society.

In the area of new energy sources, China is now developing solar energy, wind power, geothermal power, and ocean power. Progress has been made in scientific research, production, and application of new energy sources. In actuality, the development and use of new energy sources is both a distant prospect and a practical matter near at hand.

New uses must be found even as research and development is going on. For the near term, expanding the use of new energy sources will rest in finding practical solutions to the following questions:

1. Providing basic energy needs in areas where normal energy sources are not available. These areas are: wide open spaces where population is sparse, areas where transportation is poor, in the complex terrain of remote mountainous areas, and on isolated islands. There still are 32 counties in China that have no electric power, and nearly 200,000 people without electricity. One way to solve these problems is to use new energy sources. More than 10,000 small-scale photoelectric facilities, and nearly 100,000 small wind generators are already in use, making a great contribution to the society and the economy.

2. Providing a quality and reliable power supplement in areas where normal sources are insufficient, at the outer reaches of large power networks where voltage is low and line loss is a serious problem. For example, at the far end of the power network in Nei Monggol at Zhuhe where the voltage is low, five American 100 kW wind generators were started up for a test run in December 1989, and it is hoped they will partly solve the problem.

3. Setting up bases for testing new energy sources where there are fixed limitations on power for industrial production. The present technology for wind and geothermal generated power is well advanced. In Xinjiang, from Nei Monggol to the northeast, and along the southeast coast there are six experimental wind generator farms with a total installed capacity of more than 4,300 kW, among which the Nanao wind generator field in Guangdong Province has proven to be economically profitable. Further investments are being considered for building a wind power facility there for transmission of power off-island. Two geothermal areas of proven value for power generation are southern Tibet and western Yunnan where several geothermal power plants have already been built. The largest is at Yangbajing in south Tibet where seven units with a total capacity of 19 megawatts logged 300 million kWh of generated power by the end of 1988. It has become an important source of electric power for Lasa City.

Ocean power has already proved its usefulness. Eight tidal power stations and one tidal flow power station have been built with a total installed capacity of 11 megawatts. They have provided some relief in energy depressed areas, and generally have done well to show their value. Some wave power generating facilities have also been put in place and have shown their effectiveness.

Development and utilization of new energy sources is an important responsibility of the Ministry of Energy Resources. Hereafter, the Ministry of Energy Resources will give full rein to development and utilization of new energy sources, especially in promoting their application in the programming and management of key projects,

and in formulating general and specific policies for new energy sources. At the same time new energy source research in high technology areas will get close scrutiny, such as high efficiency photovoltaic technology, Hydrogen power, ocean thermal energy conversion, safer and more reliable nuclear reactors, fast neutron reactors, and controlled nuclear fusion . We hope to see the earliest possible successes and breakthroughs in the science and technology of new energy sources for the

successful development of new energy sources for China and for the benefit of all mankind.

China is going through a developmental stage of economic modernization, and we very much welcome the cooperation of technicians and all the people from the various countries throughout the world who are involved with new energy sources.

### State Council Again Reviews Feasibility of Three Gorges Project

916B0005A Beijing SHUILI FADIAN [WATER POWER] in Chinese No 8, 12 Aug 90 p 3

[Article by Yang Yi [2799 4400]: "State Council Convenes Three Gorges Project Demonstration Report Meeting"]

[Text] Three Gorges Project demonstration work concretely led and organized by the Chang Jiang Three Gorges Project Appraisal Leadership Group and carried out by the efforts and work of each of experts in each of the special topic groups and in cooperation and linkage with all areas was completed in September 1989 after 2 years and 8 months. The demonstration results and feasibility research reports were submitted to the State Council Three Gorges Project Examination Commission. After study by the State Council Work Committee recently, the Three Gorges Project Demonstration Report Meeting was held from 6 to 14 Jul 1990.

Participants in the meeting included State Council leaders, members of the coordination group, and officials from various ministries and commissions and democratic party groups, and others as well as 116 delegates from various areas.

When the meeting began, Qian Zhengying [6929 2973 5391], group leader of the Chang Jiang Three Gorges Project Appraisal Leadership Group, reported on the organizational leadership, work methods, and demonstration procedures of the demonstration work. Pan Jiazheng [3382 1367 6927], deputy group leader and senior technical official of the Chang Jiang Three Gorges Project Appraisal Leadership Group once again presented a report on the content and main conclusions of the Three Gorges Project feasibility report. The leadership group provided the following information for the meeting: 1) A report on Three Gorges Project demonstration conditions; 2) Special topic demonstration reports and appendices for the Chang Jiang Three Gorges Project; 3) The feasibility research report for key water conservancy projects on the Chang Jiang compiled by the Chang Jiang Basin Planning Office; 4) A compilation of special topic demonstration reports for the Chang Jiang Three Gorges Project; 5) Additional graphics concerning the situation in Chang Jiang Three Gorges Project demonstration work; 6) A collection of the minutes of meetings by the Chang Jiang Three Gorges Project Demonstration Leadership Group; 7) Selections from articles offering different views concerning construction of the Three Gorges Project; 8) The "People's Republic of China Three Gorges Key Water Conservancy Feasibility Report (Volume 1)" prepared by Canada's International Project Management Group Chang Jiang Joint Venture Company; 9) A summary report of the main points (revised in 1988) for the comprehensive utilization plans for the Chang Jiang Basin prepared by the Chang Jiang Water Conservancy Commission.

During the meeting, 46 experts, professors, scholars, and people from all areas gave speeches and an additional 30 comrades provided written statements. This meeting provided an opportunity for all views to be presented, those endorsing the project as well as those not endorsing the project, and everyone spoke freely and offered their own views, so it was a scientific and democratic meeting.

This round of renewed demonstration work for the Three Gorges Project was carried out in accordance with the requirements proposed in the CPC Central Committee and State Council "Notice Concerning Questions Regarding Three Gorges Project Demonstrations". In 1984, the State Council approved in principle the feasibility report for the 150 meter program for the Three Gorges Project. Subsequently, all areas offered many views. The CPC Central Committee and State Council called on the former Ministry of Water Resources and Electric Power to "re-submit a Three Gorges Project feasibility report and be concerned with accepting participation by experts with different views on the basis of soliciting a broad range of viewpoints and intensive research and demonstration. Foster full discussion and derive conclusions and opinions with a scientific foundation". This fully embodied the active and solemn principles of the CPC Central Committee and State Council concerning the Three Gorges Project. The re-compiled Three Gorges Project feasibility report and the demonstration reports from 14 special topic groups were a reflection of the achievements in research work and re-demonstration by all relevant departments and units and by the 412 experts who participated in the demonstrations over the past several decades. They are a national treasure as well as the achievements made by experts, scholars, and engineering and technical personnel who have participated in and coordinated with the demonstration work over a long period of time by burying themselves in their work, respecting science, and working hard.

After intense and heated discussion at the meeting, most delegates endorsed the special topic demonstration achievements and feasibility research reports, and some delegates offered different views and pointed out shortcomings. The meeting decided to submit the feasibility research reports to the State Council's Three Gorges Project Examination Committee for examination and expressed the hope that full consideration would be given to all the views expressed in this meeting during the examination process. Comrade Zou Jiahua [6760 1367 5478] was the chairman and comrades Wang Binggan [3769 0014 0051], Song Jian [1345 0256], and Chen Junsheng [7115 0193 3932] were deputy chairmen of the examination committee. After examining the feasibility research report, the examination committee submitted it to the CPC Central Committee and the National People's Congress for consideration.

The Chang Jiang Three Gorges Project is a huge project that is the concern of all the people of China. Its construction will have far-reaching effects on China's four modernizations drive. Demonstration work for the

Three Gorges Project is now entering a completely new stage. Besides continuing to focus closely on preparatory work, we are actively preparing to greet the examination by the examination committee.

### High Priority Placed on Hydropower Construction

906B0096A Beijing SHUILI FADIAN [WATER POWER] in Chinese No 6, 12 Jun 90 pp 2-3

[Article by SHUILI FADIAN staff reporter: "We Must Give a High Degree of Attention to Developing Hydropower—A Record of the New Year Meeting of the China Hydroelectric Power Engineering Society"]

[Text] The China Hydroelectric Power Engineering Society passed on at its 1990 New Year Meeting remarks recently made by Zou Jiahua [6760 1367 5478], member of the State Council and State Planning Commission that were recently published in a periodical: "As a primary energy resource, the amount of its hydropower resources that China has developed accounts for only about 8 percent of our developable resources. Although we will continue to rely mainly on coal for quite some time to come, we must try to give attention to and develop hydropower, utilize hydropower resources, increase the proportion of hydropower, and try to develop it as much as possible for a specific period (such as prior to the year 2000). Thus, I want to propose that we develop both hydropower and thermal power according to local conditions". Some members of the board of directors of the China Hydroelectric Power Engineering Society as well as leaders from the Ministry of Energy Resources and Ministry of Water Resources and relevant departments, and some experts and professors attending the meeting integrated with the remarks made by comrade Zou Jiahua and heatedly discussed the question of major efforts to develop China's hydropower industry. Li Eding [2621 7725 7844], Lu Youmei [7120 0147 2812], Zhang Chunyuan [1728 2504 0954], You Haoshou [3266 0679 1108], Zhu Erming [2612 1422 2494], Li Rui [2621 6904], Zhang Tiezheng [1728 6993 6927], Liang Yihua [2733 4135 5478], Shen Xinxiang [3088 0207 4382], Chen Wangxiang [7115 2489 4382], Zhang Xianhong [1728 2009 1347], Wang Shengpei [3769 5110 1014], and other comrades gave speeches.

Accelerating the development of hydropower resources certainly requires pushing forward with hydropower. This is a strategic question which concerns energy resource development and economic construction in China. Comrade Zou Jiahua has made this high level his starting point for quite some time now in repeatedly explaining and emphasizing the necessity of making major efforts to develop the hydropower industry. He also recently pointed out clearly the requirement that: "we must strive to give attention to and develop hydropower, utilize hydropower resources, and increase the proportion of hydropower". This fully embodies the concern and attention of the CPC Central Committee and State Council concerning development of China's hydropower industry. At the same time, comrades in all areas in China, including several responsible comrades in provinces (and autonomous regions) with abundant

hydropower resources, have increased their understanding of developing hydropower. By analyzing the characteristics of energy resource development in China and their own regions and experiences and lessons, they have a profound understanding that failing to make a major effort to accelerate the development of hydropower is a mistake for the energy resource industry and can create hard-to-compensate-for losses in development of our national economy. Comrades at the meeting felt that the attention and support for hydropower from all areas is a good sign and an important guarantee for promoting development of the hydropower industry. In the future, we must do further propaganda on major efforts to be concerned with and develop hydropower according to the spirit of the CPC Central Committee and State Council, and we must use persuasive materials to further explain the economic issues and advantages of hydropower to obtain greater attention and support from the relevant areas.

Comrades at the meeting pointed out that the CPC Central Committee has decided to use 3 years or a slightly longer time period to basically complete the tasks of improvement and rectification. An important goal of improvement and rectification is readjustment of the industrial structure to truly strengthen the energy resource industry and other basic industries. For hydropower, preliminary achievements have been made in this area. They are manifested concretely in total investments of about 4.2 billion yuan in hydropower during 1990, up by about 19 percent over 1989. This shows that investments in hydropower are growing simultaneously with investments in energy resources as a whole. At the same time, a large group of large and medium-sized hydropower stations and pumped-storage power stations like Ertan, Tianshengqiao first cascade, Daxia, Daguangba, Shisanling, and others have been included as construction start projects and preparation projects. This will increase the scale of hydropower stations under construction to more than 20,000 MW. Although this rate of growth is not great, it does indicate that with further improvement, rectification, and readjustment of the industrial structure, the state's slanted policies toward hydropower will be further embodied and China's hydropower industry inevitably will move out of the valley earlier and enter a period of substantial development.

Comrades at the meeting pointed out that not long ago the Ministry of Energy Resources formulated a preliminary energy resource development strategy for the year 2000. According to it, total annual power output in China will reach 1,200 billion kWh by the year 2000, including 240 billion kWh from hydropower. To attain this strategic goal, the Ministry of Energy Resources plans to focus first on developing large hydropower stations on the upper reaches of the Huang He, the trunk

and tributaries of the Chang Jiang, Hongshui He, Lancang Jiang, and so on. The state will support the establishment of regional and river basin hydropower development companies to gradually achieve cascade development of basins and make preliminary arrangements for construction and startup of 25,000 MW over 10 years. It will also take action to build medium-sized and small hydropower stations and will strive to build 10,000 MW in 10 years. Several pumped-storage power stations will be built in grids with weak peak regulation capabilities and rather large system peak-to-valley differentials. After 10 years of effort, the extent of development of China's hydropower will increase from the present figure of 8.4 percent (calculated according to installed generating capacity) to about 20 percent. It is apparent from this that our water resources and hydropower workers face extremely arduous tasks. For this reason, we certainly must have a spirit of struggle, unite as one, adhere to the principles of reform and opening up, continue to do good work in improvement and rectification, and make good preparations in ideology, organization, preparatory work, S&T progress, and other areas. At the same time, we also should actively strive to have the relevant departments provide even greater support to move hydropower onto the route of benevolent cycles as quickly as possible and create the necessary conditions and an excellent environment for developing China's hydropower industry.

#### **Paving the Way for Increased Hydropower Development**

*906B0096B Beijing SHUILI FADIAN [WATER POWER] in Chinese No 6, 12 Jun 90 pp 3-5*

[Article by Zhu Chengzhang [2612 2052 4545] of the Comprehensive Planning Department, Ministry of Energy Resources: "Create a Good Environment for Accelerating Hydropower Development"]

[Text] For the past few years, State Council member comrade Zou Jiahua [6760 1367 5478] has repeatedly used the overall situation in development of the national economy and energy resource strategy to analyze and discuss the necessity and guiding principles of major efforts to develop hydropower in China. Responding to a request from the editorial department of SHUILI FADIAN, he also wrote the inscriptions "develop hydropower, make China prosperous" and "make major efforts to develop the hydropower industry" in October and November 1989. These were a concentrated reflection of the world's experiences in energy resource utilization and development at the present time and expressed the desires of the people and embodied the concern and attention of the CPC Central Committee and State Council for developing China's hydropower industry. Comrade Zou Jiahua's inscriptions encouraged and spurred on China's several 100,000 hydropower employees and they called on us to do careful surveys, meticulous designs, and painstaking construction, shorten construction schedules, reduce construction costs, increase benefits, accelerate development, serve

the people, and bring prosperity to China. We certainly must take on the glorious task of "developing hydropower, making China prosperous" and try in every possible way to achieve it.

How can we implement comrade Zou Jiahua's inscriptions? How can we increase investments in hydropower? How can we accelerate the pace of hydropower construction? I feel that the first problem is providing an excellent environment for accelerating hydropower development.

After the People's Republic of China was established, to create excellent prerequisite conditions for accelerating hydropower development, leaders in the CPC Central Committee and State Council were extremely concerned with the cause of hydropower construction and issued several instructions calling for accelerating the development of hydropower. As a result, there were substantial developments in the development and utilization of hydropower resources in China. In 1949, China's total installed hydropower generating capacity was just 163 MW and yearly power output was 710 million kWh. After 40 years of construction up to the end of 1989, China's installed hydropower generating capacity had grown to 34,580 MW, equal to 27.3 percent of China's total installed generating capacity and sixth place in the world. Power output from hydropower reached 118.5 billion kWh, equal to 20 percent of total power output in China and fifth place in the world. At the same time, we must note that just as comrade Zou Jiahua pointed out at the National Energy Resource Work Conference, a problem has appeared in the past few years regarding the decline in the proportion of hydropower. To date, the development and utilization rate of China's hydropower resources is only 6 percent, which is not only lower than the industrially developed nations but India, Brazil, and other Third World nations as well. Why has this situation appeared? Basically speaking, after 1980, following the diversification in the sources of investments in electric power and a reduction in the proportion of state capital construction investments, the proportion of investments for large and medium-sized hydropower projects which had always relied on state investments for construction declined abruptly. During the Fourth 5-Year Plan and Fifth 5-Year Plan when the electric power industry implemented unified state control over income and expenditures, the proportion of investments in hydropower accounted for over one-third of total investments in the electric power industry. This figure declined to 27.4 percent during the Sixth 5-Year Plan and to 16 to 18 percent from 1987-1989. The outcome was that large and medium-scale hydropower projects could not be built according to rational schedules, which delayed construction schedules and increased the required investments. Construction of new projects could not begin on time and there were seriously inadequate reserve strengths. The reduction in the proportion of investments in hydropower led to a reduction in the proportions of installed hydropower generating capacity and power output in China for years in succession.



Statistics show that the hydropower capacity placed into operation as a proportion of the total installed generating capacity placed into operation was 27.6 percent in the Fourth 5-Year Plan, declined to 17.7 percent in the Fifth 5-Year Plan, was 19.4 percent in the Sixth 5-Year Plan, and only 15.7 percent in the Seventh 5-Year Plan. Plans during the Seventh 5-Year Plan stipulated that 8,210 MW in new large and medium-sized hydropower installed generating capacity would be added over 5 years but projections indicate that only about 6,000 MW can be completed. As a result, the hydropower installed generating capacity in 1990 will drop from the past level of about 30 percent to 26 percent in 1990. The proportion of power output from hydropower will drop from 24 percent in 1983 to 20 percent. Besides the problems that exist in hydropower capital construction, the shortage of capital for renewal and transformation in already-completed hydropower stations will mean that many old water turbine generators which have been in operation for over 20 years cannot be transformed, several endangered hydraulic structures cannot be reinforced and repaired on schedule, tailwater dregs accumulations on the riverbeds downstream from hydropower station plant buildings cannot be removed on schedule, many hydropower stations which urgently need expansion cannot be expanded and transformed, and hydropower stations which have already been completed are unable to provide their full benefits. Because of the small scale of hydropower construction and insufficient funds for hydropower scientific research, surveys, and design, and backward hydropower scientific research, surveys, and design, the original plan during the Seventh 5-Year Plan called for completing feasibility research reserves for 46,000 MW of large and medium-scale hydropower stations by the end of 1990, but only 26,000 MW could be completed. The original plan called for completing preliminary design reserves of 31,000 MW in large and medium-sized hydropower stations by the end of 1990, but actually only 13,000 MW could be completed. Plans for the next 10 years called for completing feasibility research for an additional 100,000 MW and preliminary designs for 60,000 MW on the basis of completing the Seventh 5-Year Plan. If we are not able to immediately increase expenditures on hydropower scientific research, surveys, and design, we may further delay hydropower construction because of inadequate design reserves. Even more serious is that because of the small scale of hydropower now under construction, some projects have stopped and started several times due to inadequate investments and other factors. Of China's hydropower construction staff of 240,000 employees along with their 550,000 family members and over 120,000 families, there are now 50,000 families living in temporary work sheds and dangerous houses at construction sites and there are 100,000 employees who are now idle. This situation has directly affected the stability of our hydropower construction staffs. This shows us the serious aftereffects of the reduction in the proportion of hydropower and thus embodies comrade Zou Jiahua's emphasis on making a conscientious solution for the problem of a reduction in the proportion of hydropower

in the past several years a primary task in doing good work on improvement and rectification in the energy resource industry. This is also one of the main reasons that comrade Zou Jiahua wrote his inscription "develop hydropower, make China prosperous". Thus, this inscription does not just begin with invigoration of China, bringing prosperity to China, improving the energy resource structure, and reducing the pressures on coal and communications. It is also a point of concern for all hydropower employees.

Why has the proportion of hydropower declined over the past several years? The direct cause in insufficient investments in hydropower and the basic reason is that an excellent environment has not been created for hydropower development in the process of reform and opening up. I feel that the problems lie in these main areas:

1. Investments for hydropower have not been arranged according to the characteristics of hydropower projects

The characteristics of hydropower are long construction schedules and an even longer lifespan of hydropower projects (the lifespan of a hydropower stations is usually set at 50 years, twice as long as a thermal power plant, but actually the hydropower stations built 100 years ago in the developed nations are still operating). For this reason, loans for hydropower projects should be loans with low interest rates and long repayment schedules (hydropower project loans provided by the World Bank and between governments, for example, have an interest rate of 3 to 8 percent and a repayment schedule of 25 to 30 years, and contain a broad time limit of 5 to 8 years). In reform of China's capital construction investment system, equal treatment was provided for hydropower and thermal power. The repayment period for the shift from allocations to loans was 15 years and for bank loans was 10 to 12 years. The interest rate has been as high as 15 to 20 percent in recent years. The construction bonds provided to hydropower projects and the loan conditions were even more burdensome than those provided to processing industries, with interest rates as high as about 30 percent, and they had to repay the loans within 3 years. Moreover, after the state arranged the investments, when the banks discovered that the hydropower projects were incapable of repaying the loans, they refused to provide the loans. Thus, when arranging hydropower investments, we should provide sufficient capital as well as investments with preferential conditions and create the ability for hydropower projects to repay loans. Otherwise, when sufficient investments are arranged the loans will still not be made.

2. No investment shares were implemented for comprehensive utilization hydropower projects

During the period of unified state control over income and expenditures, hydropower investments were made without compensation by the state and there was no need to repay the principal and interest. This made it possible for comprehensive utilization hydropower projects to

move forward without implementing investment shares. After implementation of compensated utilization of capital, hydropower investments were converted to loans. This situation requires hydropower stations to use their profits to repay the loans and requires allowing hydropower stations to bear the burden of comprehensive utilization departments (such as water-borne shipping, flood prevention, irrigation, and so on) outside of quotas with the result that hydropower requires large investments and high costs, so it cannot compete with thermal power, which places hydropower in an unfavorable status. For this reason, after implementing compensation for capital utilization, we must also implement shares for comprehensive utilization project investments and operating expenditures.

3. There is no distinction in electricity prices between peaks and valleys and between wet and dry seasons

The basic configuration of China's electric power industry at the present time is that hydropower stations with regulation capabilities are responsible for peak loads while runoff hydropower stations and thermal power plants are responsible for basic loads. As a result, the utilization time of hydropower stations with regulation capabilities is low (so the yearly power output per unit kW in hydropower equipment is low) while the equipment utilization time of runoff hydropower stations and thermal power plants is high. Power output from hydropower stations during peaks is just one-fourth to one-third that of basic load thermal power plants. In foreign countries, because the price of electricity during peaks is 3 to 6 times the price of electricity during basic loads, although the equipment utilization time at peak hydropower stations is low, their income is no lower than basic load power stations with high utilization times. This promotes the development of peak hydropower stations and guarantees grid requirements for peak regulation, frequency regulation, and accident reserves. After China implemented compensated utilization of capital, no distinction was made among electricity prices for peaks, basic loads, and wet and dry seasons in power station financial accounting. All were calculated according to an average price for electricity, which was extremely unfavorable for peak power stations. The result was that everyone set out to build thermal power plants and runoff hydropower stations without regulation capabilities.

4. Unreasonable demands are placed on hydropower projects for paying cultivated land occupation taxes

Rational utilization of hydropower resources requires construction of regulation reservoirs with a water storage capability. Hydropower station reservoirs usually provide comprehensive utilization benefits like flood prevention, water-borne shipping, irrigation, water supplies, tourism, and so on and reclamation of considerable cultivated land can be protected downstream from some reservoirs because of higher flood prevention standards, so hydropower projects undoubtedly are projects which create prosperity for the people. At present, hydropower projects must assume

responsibility for investments in comprehensive utilization departments and funds to compensate for resettlement and land occupation in reservoir regions as well as take responsibility for cultivated land occupation taxes, which obviously is unreasonable. At present, water conservancy, airport, highway, and other public facilities can be exempted from cultivated land occupation taxes but electric power (including hydropower stations) which are a uniquely important public industry must remit cultivated land occupation taxes. The collection of cultivated land occupation taxes from hydropower stations places hydropower in an unfavorable position compared to thermal power, and it places hydropower stations with regulation capabilities (those with rather large reservoirs) in an unfavorable position compared to runoff hydropower stations (which basically have no reservoirs).

5. No consideration has been given to the distribution and development characteristics of China's hydropower resources

China's hydropower resources are located mainly in southwest and northwest China. These areas have abundant hydropower resources and large-scale hydropower stations. After 40 years of developing China's hydropower resources, large and medium-sized hydropower stations have basically developed all of the hydropower resources in east China, so the future focus of large and medium-sized hydropower development will shift to west China. During the process of implementing "dividing up the stoves to eat" [transferring control over projects to lower levels] and diversification of electric power investments, no consideration was given to these two characteristics of hydropower development in China. The result was that although west China had abundant hydropower resources it had a poor capability for raising capital and the 0.02 yuan per kWh requisitioned for use as an electric power construction fund was small (because the region produced and used less power than east China and most users were high power-consuming enterprises, they were exempt from paying the electric power construction fund). East China has a powerful economy, more electric power construction funds, and a stronger ability to raise capital, so under conditions of "dividing up the stoves to eat" the state had no regulation authority and east China was unwilling to invest in building hydropower in west China, so the result was that west China had insufficient capital to develop hydropower.

In light of this situation, the state should do comprehensive research on the relevant policies based on the characteristics of hydropower construction and create an environment that is conducive to accelerated development of hydropower construction. I propose the adoption of these measures:

1. Establish stable capital sources for hydropower construction

The electric power industry is a public industry and development of the electric power industry must rely on

the large number of electricity users. Users use their power fees to pay the capital required for investment to build new power plants and develop large power grids. This requires formulation of rational electricity prices, lowering tax rates, reducing the number of taxes, and turning electric power enterprises into self-managing economic entities with stable capital sources. This will be hard to accomplish in one stroke at the present time, however, so some emergency measures can be adopted:

1) Increase the proportion of investments in hydropower for capital arranged by the state for electric power construction. There has already begun to be an increase in this proportion in 1990. 2) The electric power construction fund requisitioned from power generated by hydropower should be centralized by the state and used to build large hydropower stations. 3) Low interest loans from international financial organs and governments can be utilized by large hydropower stations with the state providing for unified borrowing and repayment and the hydropower stations being responsible for paying the state an amount of renminbi equivalent to the principle and interest of the foreign capital. 4) Mobilize local areas, departments, and enterprises to raise capital to develop hydropower. 5) Delay the shift from allocations to loans and the time period for repayment of bank loans as appropriate and reduce interest rates as appropriate, or have the state subsidize the interest.

2. Implement investment shares for comprehensive utilization hydropower projects

All hydropower projects with comprehensive utilization benefits should implement investment and expenditure shares. This portion of the investments should not be included in the fixed assets of hydropower stations and hydropower stations should not be responsible for repaying the loan principal and interest. Comprehensive utilization departments should share the investments and expenditures and take into account the economic conditions in areas where hydropower projects are located, with local areas and the state assuming responsibility for the appropriations.

3. Strive to formulate peak, basic load, and wet and dry season electricity prices

Matters should be handled according to the law of value, with top prices for top quality. Under conditions of unchanged electricity prices, formulate rational peak electricity prices, basic load electricity prices, wet season electricity prices, and dry season electricity prices.

4. Exempt hydropower projects from the cultivated land occupation tax

Development-type population resettlement measures should be adopted in hydropower construction. Reservoir resettlement and occupation subsidies should be used to help the resettled population develop sideline industries, processing industries, and agriculture and take conscientious responsibility for making proper arrangements for the production and lives of resettled

people. Increase reservoir maintenance funds as appropriate and have the Ministry of Energy Resources centralize the funds to support the development of production in the area where the population is resettled and make good arrangements for the resettled population's livelihood and reservoir region construction. In this situation, they should be exempted from the cultivated land occupation tax.

5. Establish two special funds for preparatory work and construction enterprises

Include hydropower preparatory work funds and construction enterprise special funds in the costs of hydropower stations that have already been built to speed up preparatory work and solve the problems faced by hydropower construction enterprises. At the same time, I hope that the State Planning Commission will provide more technical transformation loans to accelerate technical transformation and expansion projects at hydropower stations. The State Science and Technology Commission should provide more hydropower scientific research funds. In summary, I hope that everyone will promote the development of hydropower and create an excellent environment of equal competition for hydropower construction.

#### Formulation of Long-Term Program for Hydropower Development

916B0005B Beijing SHUILI FADIAN [WATER POWER] in Chinese No 8, 12 Aug 90 pp 4-6

[Article by Wu Hongzhong [0124 1347 0022] of the Central Water Resources and Electric Power Planning and Design Academy: "Work to Undertake Long-Term Hydropower Development Planning Work, Conscientiously Prepare Good Hydropower Macro Policies"]

[Text] Hydropower planning is work that has strategic significance for hydropower construction and it is the foundation for long-term strategic deployments in hydropower construction. The quality of hydropower planning work is linked directly to fostering the benefits of investments in electric power and it concerns the questions of whether or not we will be able to better develop China's abundant hydropower resources, improve the energy resource structure of China's electric power industry, speed up the pace of electric power construction, and quickly change the passive situation in which our electric power industry lags behind the needs of developing the national economy.

In the 40 years since the nation was founded, many increasingly complex problems have been presented to hydropower planning as electric power systems have expanded (or grids have been interconnected) and as the number of hydropower stations has grown. For example, there are questions concerning a rational primary energy resource structure and ratio between hydropower and thermal power, a rational extent of development for regional hydropower resources, a rational degree of runoff regulation for regional hydropower station clusters and geographic distribution of

regulation reservoirs, optimum development sequences for rivers and hydropower cascades, the development of systems arising from large-scale hydropower construction and formation of primary grid frameworks, and so on. These problems cannot be solved by hydropower cascade development programs and project programs (economic assessment of projects and selecting project scales) for rivers, but must be solved through study of long-term hydropower development programs for regions (or multiple regions).

There are now many problems in hydropower construction that urgently require solution and we must study and solve them. They include, for example, rational ratios between hydropower and thermal power in electric power systems in southwest, northwest, and south-central regions of China which have abundant hydropower resource reserves; rational development sequences and selection of degree of hydropower regulation and reservoirs for the Yalong Jiang, Jinsha Jiang, Dadu He, and other main rivers in Sichuan, which are related to an early turnaround in the long-term power shortage in Sichuan Province and the problem of achieving an upswing in hydropower; rational development sequences for the various cascade power stations on the Lancang Jiang in Yunnan Province and the Wu Jiang in Guizhou Province; the question of building medium-sized hydropower stations; the question of developing huge power stations in the Three Gorges and on the Jinsha Jiang; the scope of power supply by large hydropower stations and the question of "transmitting power from west China to east China"; measures for peak regulation in regional electric power systems which lack hydropower resources and have attained full development and the question of building pumped-storage power stations, and so on. Thus, major efforts to undertake long-term hydropower development planning cannot be delayed.

The object of research on long-term hydropower development programs is strategic principles for long-term development of hydropower in a region (or several regions). It should begin with long-term demand for electric power in a region (or multiple regions), the energy resource situation, and the characteristics and development conditions of hydropower resources to study the question of hydropower development, which means that it should consider both the spatial breadth and the temporal length. The content of long-term hydropower development programs generally includes the following aspects:

1. Research on a rational primary energy resource structure (ratio between hydropower, thermal power, and nuclear power) for the electric power industry of a region (or multiple regions);
2. On the basis of selecting power sources for an electric power system, determination of a rational development sequence for the rivers of a region (or multiple regions) and for cascade power stations on each river;

3. The degree of runoff regulation for hydropower stations in a system and selection of a geographic deployment for regulation reservoirs;

4. Research on hydropower-thermal power and hydropower-hydropower compensated operation patterns on their benefits;

5. Research on the question of system peak regulation;

6. Rational configuration of installed generating capacity in hydropower station clusters in a system;

7. Research on the questions of electric power system primary grid frameworks and grid interconnections and on long-distance power transmission (such as transmitting power from west China to east China);

All these aspects are interlinked and mutually restrictive, and all of them are carried out surrounding the question of hydropower development. They can be considered somewhat more imprecisely for thermal power and system questions. For the hydropower question, they should be emphasized and simplified to deal with concrete conditions in each region.

Long-term hydropower development plans are mainly used for:

1. Providing ideas for arranging hydropower construction projects;
2. Providing ideas for arranging preparatory work for hydropower;
3. Providing guiding information for hydropower station design such as system energy resource structures, hydropower-thermal power ratios, system integration, scope of power supply by power stations, system power sources, hydropower-hydropower and hydropower-thermal power compensated operation patterns and the related economic information (such as marginal system expenditures, etc.). This information bears an important relationship with hydropower station design. Without this type of information, any economic appraisals of hydropower stations are blind ones and correct conclusions cannot be drawn.

Some long-term hydropower development programs which are used for hydropower resource development and utilization should be carried out on the basis of river cascade programs and comprehensive utilization programs, so there must first of all be good river cascade and comprehensive utilization programs. In contrast, however, long-term hydropower development programs also should inspect and revise river cascade programs and comprehensive utilization programs. Because there are some questions (such as configuration of reservoir capacities and cascade programs), when making river program cascades and comprehensive utilization programs, since no regional programs have been carried out, it is possible

that they may have certain limitations, so it is entirely necessary that revisions be made in river cascade programs and comprehensive utilization programs within long-term hydropower development programs.

As a part of energy resources, long-term hydropower development programs also must be carried out (if they exist) on the basis of regional (or multi-regional) energy resource programs. If there are temporarily no energy resource programs, the relevant information (such as power coal reserves, balanced production, transport, and marketing, and so on) can be collected from related departments and understood to carry out analysis and adoption, and when necessary research can be carried out according to several possibilities. After a long-term hydropower development program is completed, feedback can also be provided to energy resource programs for reference in revising energy resource programs.

The relationship between long-term hydropower development programs and electric power system development programs is a complementary one and they are used for mutual consultation, mutual compensation, and mutual revision. When doing research on long-term hydropower development programs, consideration should be given to the question of electric power system development programs and the optimum program should be selected for the entire system. Moreover, long-term hydropower development programs can serve as a foundation for system programs because when hydropower accounts for a definite proportion in an electric power system, the program for that electric power system to a substantial extent involves optimized hydropower development and the electric power system cannot be detached from the energy resource structure, operational patterns, grid interconnections, or other areas. Thus, electric power system programs certainly must be carried out on the basis of long-term hydropower development programs. However, system programs in turn should be used to examine and revise long-term hydropower development programs (especially in relation to the question of long-distance power transmission). The view that compilation of long-term hydropower development programs can be detached from electric power system development programs or that electric power system development programs can be carried out on the basis of subjectively determined ideas for hydropower development is inappropriate.

To enable close integration of long-term hydropower development programs with system programs and thermal power programs, system and thermal power programs and the related ideas must be collected and understood when preparing long-term hydropower development programs.

The planning period for long-term hydropower development programs is usually 15 to 30 years. The planning periods for medium-term and short-term hydropower development programs are usually 10 and 5 years. The

latter is carried out on the basis of long-term development programs and is used to supplement and revise long-term development programs.

A long-term hydropower development program has certain strict qualities, but it is not permanent. It must be rolled as time passes, referring to "program rolling", usually once every 2 or 3 years. When situations or tasks change, it should be supplemented and revised according to the changes in situations or tasks, for example:

1. When there are substantial changes in system integration, system loads, or power sources;
2. When there are substantial changes in program tasks or when new problems must be studied;
3. When there is new information on hydropower power sources participating in the program and when there are substantial discrepancies between the new information and old information;
4. When there are substantial changes in the comprehensive utilization tasks of the larger hydropower stations in the original program which would have significant effects on program decision-making;
5. When the scope of a program or the period of a program is different than the original program;
6. When there are substantial changes in state economic policies or electric power construction principles.

In general, a long-term hydropower development program should adhere to the following principles and requirements:

1. It must be guided by system engineering ideas, make full-system optimization the starting point, use minimum full-system total expenditures converted to cash as the standard for optimization, and consider other non-economic factors for comprehensive evaluation to select programs;
2. It must consider the technical economics factors of primary energy resource development and secondary energy resource conversion, transmission, supply and demand equilibrium, and other primary links;
3. It should consider and integrate the long and short terms, which means they must have long-term strategic views as well as short-term tactical goals;
4. It should fully embody the characteristics of hydropower, and in particular should give full consideration to the gain from hydropower station "clusters", and it should be able to deal properly with the relationships among each of the parts of the clusters;
5. The sequence of work usually moves from the macro view to the micro view, meaning that it starts with long-term programs and then moves on to medium-term and short-term programs. It first prepares programs for a large region and then prepares programs for small regions;

6. The demarcation of each stage should be determined according to concrete needs. Usually, long-term programs can be somewhat longer and shorter term programs should be somewhat shorter. Sometimes, to deal with the short term and the long term, demarcation can be carried out according to the principle of doing the short term first and the long term later.

Long-term hydropower development programs involve enormous and complex systems engineering, require solution of many problems, touch on a very broad range of areas (from development of primary energy resources to consumption of secondary energy resources), and involve long program periods. Many factors must be considered and there are very complex technical questions, especially the non-linear characteristics of hydropower station investments (dams and reservoirs must be built before generators can be installed) and the question of gain from hydropower station "clusters" (created by runoff regulation through linkages of cascade hydropower and multi-region compensation runoff regulation), which greatly increase the difficulty of programs and make them far more difficult than thermal power programs. This is the main reason that many electric power program models in various countries of the world are capable of finding good solutions to the problem of optimized programs for thermal power and system development while they are unable to solve problems of optimized programs for hydropower. Over the past 10 years, many planning and design units, institutions of higher education, and scientific research units in China have done a great deal of work on optimizing hydropower programs and provided many beneficial achievements. They have local analog models and local optimization models, and a substantial portion of them have been used in actual program design with gratifying results. This is particularly true for their success in the structure of the interregional electric power program model IRELP/I and it has been used successfully in long-term power source planning in Sichuan Province. This is a major breakthrough in long-term hydropower development programs and it has special qualities in the area of hydropower optimization and has attained advanced international levels. Because various types of models have been used as tools and computers are used as the means, a foundation has been laid for long-term hydropower development programs which will enable the formulation of a good long-term hydropower development program in the next few years. Still, because of the complexity of long-term hydropower development programs, simply relying on a small number of models is not sufficient and we should continue to build new models. Existing models also should be continually supplemented, revised, and perfected. We should continue to use conventional methods which have been effective. In certain situations, optimized methods should be used in conjunction with conventional methods because originally there was no unbridgeable chasm between conventional methods and optimized methods. Optimized methods "arose from convention and rise above convention" and "today's optimum is tomorrow's convention".

To do good long-term hydropower development programs, we: 1) Must have reliable basic information as a

foundation, including system load requirements, hydropower, thermal power, (and other power sources), the corresponding fuel base areas, and technical and economic information, and we should strive to unify them on the same foundation. When the required information is absent or unreliable, the model must still be perfected but we cannot prepare a correct program. As a result, we should make a major effort to collect and analyze basic information, including further reinforcement of hydropower survey and research work, in the greatest possible effort to avoid the phenomenon of substantial increases in hydropower station investment budgets (excluding materials price factors). 2) We should try to establish hydropower program databases as quickly as possible. We have done a great deal of hard work in this area and expended considerable effort on data, but we often make mistakes. It is unthinkable to have no corresponding database to serve as a foundation for a large-scale program. However, this type of database should be established based on program requirements, used as it is established, and continually expanded and perfected. I propose establishing a central repository in Beijing at the Central Water Resources and Hydropower Planning and Design Academy and each related survey design unit should establish sub-repositories to achieve a unified data structure, unified data system, and unified data. 3) We must reinforce leadership and organizational work for long-term hydropower development programs, strengthen planning staffs, continually renew the knowledge of the personnel involved, gradually improve the quality of the personnel involved, adopt various measures to stabilize the work posts of hydropower planning personnel, establish a hydropower development program examination and approval system, and implement program achievements.

### **Building Medium-Sized Hydropower Facilities in Coal-Short Regions**

916B0005C Beijing SHUILI FADIAN [WATER POWER] in Chinese No 8, 12 Aug 90 pp 7-10

[Article by Ding Xueqi [0002 1331 3823] of the China Water Conservancy and Hydropower Project Consulting Company: "Create the Conditions for Building Several Medium-Sized Hydropower Stations—Some Ideas on Medium-Scale Hydropower Project Design Optimization"]

[Text] State administrative departments have pointed out that we should rely on local strengths to build several medium-sized hydropower stations with good benefits which produce results quickly in a planned and gradual manner in regions which have hydropower but lack coal before the year 2000. This is a heavy and urgent task. I feel that in this task, our ability to attain the requirement of "good benefits, quick results" is the key question. The reason is that since the system reform, construction of medium-sized hydropower stations has relied mainly on capital raised by local areas, while most of the prefectures and counties where the power stations are located are in "old revolutionary base area, minority nationality, frontier, and poor" regions so it is not easy to squeeze out a little

extra capital. Only through "good benefits, quick results" will they be able to raise capital easily and enable the projects they build to create prosperity for the people in these regions as quickly as possible. From the medium-sized hydropower stations to be built in the short term that I have come into contact with during the past year, "good benefits, quick results" makes major efforts to focus on preparatory work essential. On the basis of doing good river (river segment) planning, boldly adopt mature experiences and advanced scientific and technical achievements and conscientiously do good design optimization. In this area, there are both urgent needs and bright prospects. I will offer some views in eight areas below for joint discussion by the relevant comrades.

### **I. Build Stations Below Reservoirs With Regulation Capabilities**

Many medium-sized hydropower stations at present are of the runoff type so this to a certain extent affects the benefits of the power stations. Given this sort of situation, it would be best if we chose already-constructed reservoirs (hydropower stations) with regulation capabilities to build medium-sized hydropower stations downstream. This would provide many times the benefits with half the effort. An example is the Wangpuzhou Key Water Conservancy Project on the Han Jiang in Hubei that was built downstream from the Danjiangkou [Dan Jiang mouth] reservoir. A great deal of construction and installation engineering was required for this project because it was built by blocking the river and has a shoal, and because it has a low head (the maximum dam height is 12 m), long dam line (the total length of the sluice gates and dam is about 18 km), large floods (the calibrated floodwater is nearly 30,000 m<sup>3</sup>/s), and complex geological conditions (there are widespread fine sand strata at the dam base), but because of regulation by Danjiangkou reservoir, the installed generating capacity of this project is 109 MW and it can attain guaranteed output of 38 MW and yearly power output of 590 million kWh. Added to the short construction schedule up to the time power was generated, it has unfavorable conditions but rather good benefits. With suitable electricity prices, it could still be competitive. Gaotan Hydropower Station on the You Shui in Hunan is another low head power station. Because the Fengtan reservoir upstream provides regulation, it has an installed generating capacity of 56 MW and can generate 280 million kWh of power annually. Moreover, it plays a reverse regulation role in capacity expansion at Fengtan Hydropower Station and in water-borne transport downstream, so all administrative departments in Hunan Province are unanimous that it should be the first medium-sized hydropower station for construction in the near term. Jiangxi is now building Daduan Hydropower Station on Shankou Shui, a tributary of the Xiu Shui which will have a reservoir capacity of 113 million m<sup>3</sup> and a regulable flow rate of 13.7 m<sup>3</sup>/s. On the Dongjin Shui, another tributary, preparations are being made to build the Dongjin Shui Hydropower Station in the short term with a reservoir capacity of 634 million m<sup>3</sup> and a regulable flow rate of 23.2 m<sup>3</sup>/s. In this

sort of situation, if we can speed up preparatory work for Baozishi Hydropower Station on the trunk of the Xiu Shui and strive to build it as quickly as possible, we will be able hold the water inside the river trough and will not have to do a great deal of engineering work, but will still have an installed generating capacity of about 24 MW and be able to generate about 123 million kWh of power annually. Both of these examples fall within the scope of river planning, but they illustrate the need to take full advantage of existing conditions and select the best locations below reservoirs with regulation capabilities to build power stations, so this must be one of the most urgent tasks at the present time.

### **II. Divert Water From Several Rivers To Develop Medium-Scale Hydropower**

Diverting water from several rivers to develop medium-sized hydropower stations can provide head and concentrate runoff, which will expand the economic benefits of projects and improve the quality of power supplies, but there are few examples of this in China to date. Development of distant tributaries, especially development of the upper reaches of tributaries, involves limited inundation but has no water collection area, whereas cascade development by diverting water from many rivers can convert unfavorable conditions into favorable ones. An example is Luowan Hydropower Station, which has already been built on the North Qing'an He, a tributary of the Liao Shui in Jiangxi. Water was diverted from the river to North Liao Shui Hydropower Station to obtain a head of 187 m, an installed generating capacity of 18 MW, and a regulable flow rate of 3.6 m<sup>3</sup>/s. This can increase the regulable flow rate for Gaohu Hydropower Station planned for linked construction on the North Liao Shui by more than 50 percent, which will increase the comprehensive utilization benefits of Gaohu and permit consideration of Gaohu simply in terms of power output, which is more advantageous. Another example is the Songjiang He cascade now being designed in Jilin which will employ a development program that diverts water from the Man Jiang and combines the Man Jiang and Songjiang He. The results of comparing research done over many years indicates that although diverting water from the Man Jiang would provide no benefits in terms of head, it could result in investment savings of 20 to 30 percent because it takes full advantage of a favorable river segment and simplifies the cascades.

### **III. Utilizing River Bends To Deploy Key Power Station Facilities**

Most places where there are river bends have single thin mountain ridges near the river. Using these single thin mountain ridges for deployment of key water conservancy projects can increase the head but even more importantly can simplify the key projects and reduce the construction schedule for power generation. There are many examples of medium-sized power stations with this type of configuration. An example is Doulingzi Hydropower Station on the Jia He in Hubei, which will be built soon. The reservoir capacity at normal high water levels is 349 million m<sup>3</sup>, the



maximum dam height is 85.5 m, the installed generating capacity is 60 MW, and the calibrated floodwater flow rate is 11,600 m<sup>3</sup>/s. This project will utilize a mountain ridge formed on the right bank by a bend in the river and strip of land between two hills for deployment of a key project. This will provide an additional 1 meter of head and will permit diversion and sluice tunnels less than 250 meters long and there will be no interference among the various hydraulic structures. Another example is the planned cascade Ruoshui Hydropower Station on the Wu Shui in Hunan where a configuration similar to the one just described is being adopted, and a rafting channel around the dam will also pass through a strip of land on a mountain ridge on the right bank downstream from the power plant. This will increase the head by 4 meters and will open up two dangerous shoals in the shipping channel from below the dam in the river channel between the power plants. Preliminary plans call for a maximum dam height of about 60 m and it may be able to generate power within 2 to 3 years. The Dongjin Hydropower Station mentioned previously basically will also adopt a river bend configuration program.

#### IV. Building Dams from Local Materials

Most of the sites chosen for development of medium-sized hydropower are located in frontier mountainous regions where industrial construction materials are not easily obtained and transportation is inconvenient. As a result, efforts to obtain materials locally historically has been an important way to reduce construction costs and facilitate project construction. Further integration of the experiences of the masses with modern science and technology will open up even broader prospects for obtaining materials locally. China has mature experiences in using various types of sand, rock, and earth (red soil, gravel soil, pebble soil, ballast, and so on) to build dams and the development of vibration tamping, using weathered material as leakage prevention bodies, and other technologies in the modern era have created the conditions for further opening up the scope of obtaining materials locally, expanding the scale of engineering uses, and accelerating the pace of project progress. The masses in many regions of China have experience in laying brick to make arches. Statistics indicate that over 80 percent of the 30 m and taller arch dams already built in China are laid brick arch dams. The thinnest is probably the Fangkeng dual-arch dam at Wuyi in Zhejiang (the dam is 70 m tall and has a thickness-height ratio of 0.147 and an arc-height ratio of 2.16). The tallest is the Qunying gravity arch dam at Jiaozuo in Henan (the dam is 100.5 m tall and has a thickness-height ratio of 0.52 and an arc-height ratio of 1.54). The application of modern arch dam technologies has resulted in the use of variable thickness and partial flattening for dam bodies and diversification in dam surface leakage prevention materials along with the use of electronic computers in calculations and fine stone concrete for brick laying, and so on, and laid brick arch dams are developing in the direction of high and thin. The Jinggangchong Hydropower Station now under construction at Jinggang Shan in Jiangxi has an installed generating capacity of 12 MW and a maximum dam height of 92 m. It is a laid brick arch dam which uses fine stone concrete. Although the

geological conditions for the dam abutments on both banks are not favorable, optimization of the dam body type permits a relatively thin dual-arch arch dam (thickness-height ratio 0.275, arc-height ratio 3.46).

#### V. Using New Dam Types and New Technologies

There have been quite a few innovations and new attempts in large dam types and construction technologies in recent years. Medium-sized hydropower projects can be adapted to local conditions through active selection and trial points. Rolled concrete gravity dams are developing very quickly in China and they are being used in quite a few projects, even in large primary projects. Rolled concrete arch dams are now being tested at the Puding Hydropower Station Project on Sancha He in Guizhou. This project has a reservoir capacity of 318 million m<sup>3</sup>, an installed generating capacity of 75 MW, and a maximum dam height of 75 m. The width of the dam base is 33 m, the thickness-height ratio is 0.413, and the arc-height ratio is 0.218. To facilitate rolled construction, the cross-section of the large dam is vertical upstream and has a 1:0.25 slope downstream. Concrete dual-arch dams are also developing in the direction of tall and thin. Quanshui Hydropower Station at Ruyuan in Guangdong now under construction is renowned for its thin dam which has a maximum dam height of 80 m, a dam foundation 9 m wide, a thickness-height ratio of 0.112 and an arc-height ratio of 0.261. Longtan Hydropower Station on the Shangyou Jiang in Jiangxi where preparations for construction are now underway will have a total reservoir capacity of 116 million m<sup>3</sup> and an installed generating capacity of 40 MW. Parameters related to the Ertan arch dam will be adopted for the dam body type and the dam height will be 90 m, the width of the dam base will be 11 m, and it will have a thickness-height ratio of 1.22 and an arc-height ratio of 2.75. In addition, tests of cement modification and the adoption of compensated contraction concrete in dam structures are now being organized at gravity dams or arch dams. After tests of steel-reinforced concrete faced stone-fill dams at Guanmen Shan in Liaoning and Xibeikou in Hubei, they have been rapidly extended because they can conserve investments, simplify the configuration of key facilities, and shorten construction schedules. Baiyun Hydropower Station at Chengbu in Jiangxi which is planned for construction soon will have a total reservoir capacity of 320 million m<sup>3</sup>, an installed generating capacity of 50 MW, and a dam height of 110 m. It will use a steel-reinforced concrete faced stone-fill dam program. There are successful examples of building earthen dams on capping strata in river beds (such as Miyun Reservoir in Beijing), concrete gravity dams (such as Shangmaling Hydropower Station on the Yongding He), and arch dams (Zhaixiangkou Hydropower Station on the Maotiao He in Guizhou). There have been many advances in riverbed capping strata reinforcement and leakage prevention processing



techniques in the past few years including vibration shock, rotary spraying, compression grouting, and so on. The application of these new technologies can lead to faster, cheaper, and more reliable projects. It should be pointed out that the use of dam body floodwater discharge at both Shangmaling and Zhaixiangkou greatly increased the difficulty and complexity of washout prevention processing of the capping strata, which made their economic benefits less than obvious. Usually, medium-sized hydropower stations do not have large floodwater flow rates, so they do not need to use dam body flood discharging. If this is taken into consideration, there is no need for excavation and filling to build a dam on capping strata, which saves investments, shortens construction schedules, and produces extremely obvious economic benefits.

#### **VI. Use a Configuration Program for Multiple Uses of a Single Tunnel**

In the past, many water conservancy and hydropower projects used a project configuration program in which a single tunnel was used for many purposes. At Gangnan Reservoir in Hebei, for example, one tunnel is used for power generation and floodwater discharging and for irrigation and floodwater discharging. There are many examples, even at large projects, where flow diversion and power generation are combined or flow diversion and floodwater discharging are combined. Usually, medium-sized hydropower stations do not have large floodwater flow rates (less than  $3,000 \text{ m}^3$ ) or high heads (dam heights are less than 100 m) which in addition to improved high-velocity current prevention measures and lock levels have created the conditions for using one tunnel for multiple purposes. Baiyun Hydropower Station in Hunan which was mentioned previously is a perennial regulation reservoir and has few opportunities to discharge floodwater. The calibration flood of the project is only  $2,460 \text{ m}^3$  and the original design used spillways on the banks to discharge floodwater, so the side slopes required processing. In addition, because the diversion tunnels were rather small in diameter and construction was done during a single dry period on a clean foundation where the flow had been blocked, a 60 meter high stone-fill dam temporary cross-section structure had to be built to allow the floodwater to transit, so the construction schedule was rather tight. With research on eliminating spillways and suitable increases in the diameter of diversion tunnels to combine them into floodwater discharge tunnels in conjunction with simultaneous research on changing from four generators to three units, the fourth branch pipe can be used as an air release branch tunnel through the plant building during installation, which can simplify the project and aid in floodwater blockage and transit for large dams, and it can save substantial investments.

Water diversion and transmission tunnels can use simple brick liners and reduced tunnel diameters according to actual conditions. Selection of tunnel lines should permit burial at slightly greater depths with consideration of geological structure conditions to increase the thickness

of the surrounding rock above. Usually, unless some steel lining is necessary near the plant building and at the outlet of the tunnels, it is usually best not to use steel liners to simplify construction procedures and conserve investments. In some situations, lining-less, shotcrete, prestressed, and other types of lining arrangements can be used. To select optimum tunnel diameters, the body of the tunnels usually should not account for a substantial proportion of the loss of head. When regulation and protection computer control is available, segmented shutdown and other measures also can be adopted.

#### **VII. Select Appropriate Survey and Design Standards**

On the basis of revised standards, the floodwater standards of key hydraulic facilities, floodwater discharge energy dissipation, and construction flow diversion can be reduced somewhat on the basis of summarizing practice. Thus, the design standards for actual structures should be chosen appropriately. It usually is best if the floodwater discharge capacity of floodwater discharge structures are targeted on reservoir inundation compensation standards. In situations when there is limited inundation by tributaries in mountainous regions, floodwater in excess of compensation standards can be dealt with by using over-storage arrangements. By retaining a specific amount of excess height, the expense is not much greater for earthen dams or arch dams and comprehensive calculations for the project can conserve investments. This is especially true for earthen dams. When there is a possibility of landslides near the dam or on the banks of a reservoir, they may also have the benefit of preventing the effects of surge waves in the surrounding area. Selection of floodwater discharge structure ports also should be done in conjunction with geological conditions and operational patterns (such as selecting tunnels or sluice gate sections with relatively perfect open energy dissipation facilities to increase the downstream water cushion) and increasing the dimensions of sluice gates and the single-width flow rate for floodwater discharging to compress the leading edge of the overflow as much as possible. Technical developments in existing sluiceway levels and floodwater energy dissipation facilities (narrow fissure type, broadtail mounds, bail-type, irregular banks, etc.) can provide an excellent solution to the problem of large single-width flow rates.

There also should be suitable requirements for the depth of survey work for medium-sized hydropower, meaning that we cannot ignore key geological questions and the necessary survey and experiment work, nor can the requirements be too complex. This is especially true for some problems that can be clarified only by spending money and time. We should try as much as possible to use analogous assessments on the basis of clarifying basic geological laws, such as the mechanical parameters of rock bodies, or by additional remedies in design programs such as the development of gentle soft interbeds at the foundations of dams. The slide stability of shallow strata at dam abutments and dam foundations can be designed according to unfavorable critical conditions.

Because the heads involved are not very high, the borrowing of measures in the structure of hydraulic structures often does not cost very much.

There should be appropriate simplification of the number of generators installed and the cut-in system design. Under permissible conditions of system operation, it is best if the number of generators is somewhat smaller since this can lead to both civil engineering and electromechanical savings. Output lines should consider the needs of both power grids and regions, but it is not appropriate for hydropower stations to be made into regional power transformer stations so that most of the output lines at certain medium-sized hydropower stations have 3 to 4 voltages and over 10 loop circuits. Automation levels in power stations should be adapted to our national conditions and it is even less appropriate for us to pursue remote control or even having no one on duty.

#### **VIII. Create the Conditions for Power Stations To Generate Power and Produce Benefits Ahead of Schedule**

Since we began paying attention to the economic and dynamic benefits of hydropower, the question of generating power ahead of schedule has attracted even greater attention in all areas, so we should create the conditions for generating power ahead of schedule from design programs to construction arrangements. When the flow can be diverted in stages in broad riverbeds, we should utilize the conditions of two-period weirs to generate power, but this must be implemented in the design program. In the design for Gaotan Hydropower Station on the You Shui in Hunan described previously, the key facilities are composed of a riverbed power station, 24 floodwater discharge gates, and a rafting channel around the dam on the bank. The flow will be diverted in stages. During the first stage, the power plant and 12 floodwater discharge gates on the left bank will be enclosed and water will pass through the weir. The construction schedule is 28 months. During the second stage, 12 gates on the right bank will be enclosed and the earthen weir will capture the water for power generation. The construction schedule is 9 months. Studies indicated that the program was feasible, but it required further implementation: during the first period, water will have to transit the power station plant building in the base pit on two occasions, so the 28-month construction schedule is too tight (they will use bulb-type generators), whereas water transit and water bubbling cannot be permitted at the plant building during the second wet season, so it is best to use a guide wall between the building and dam and to form a small base pit for one of the plant buildings in the first-period base pit in an effort to achieve year-round construction. All the civil engineering and metallic structure installation for the 12 gates will have to be completed in 9 months in the second-period base pit and there is no leeway. It is best to study measures for allowing the water to transit the second-stage earthen weir to ensure the storage of water for power generation. For key projects having high dams in narrow riverbeds, it is best to integrate with the overall configuration of the project to enable closing of the gates to store water ahead of schedule in the water discharging structures

for flow diversion and low water levels and to facilitate the conditions for transit operation. Designs for large dams also should take into consideration design conditions for storing water ahead of schedule in an effort to generate power ahead of schedule. Prefabricated assembly and other measures also can be utilized for certain assemblies used in low gates and the above-water portions of plant buildings.

There are many ways to optimize designs for medium-sized hydropower stations and there is great potential. I am providing the eight problems I laid out above that I have encountered in my work for the reference of comrades. At the same time, I also hope that they will promote wide-ranging development of work in this area and thereby create favorable conditions for pushing forward with construction of several "good results, quick benefits" medium-sized hydropower stations before the year 2000.

#### **Tianshengqiao To Play Major Role in Supplying Energy-Starved East**

906B0102 Guangzhou NANFANG RIBAO in Chinese  
14 Jul 90 p 1, 3

[Article by NANFANG RIBAO reporter Huang Jingtang [7806 6975 2768]: "A Major Undertaking in 'Transmitting Power From West China to East China'—Guangdong Providing Half of Total Investment for Tianshengqiao Hydropower Station Construction Site on Border of Guizhou and Guangxi Zhuang Autonomous Region"]

[Excerpts] [passage omitted]

#### **I. The Urgent Requirements of Economic Development in South China**

I travelled by car southwest from Guiyang to the remote mountainous region of Southwest Guizhou Bouti-Miao Autonomous Prefecture on the exotic and dangerous winding 18 Panshan Road through Anshun and Huangguoshu, and onto the highway running through the sheer cliffs along both banks of the Hua Jiang. I saw the roaring and thundering river water beneath tall cliffs that made me dizzy. This was the rainy season in Guizhou, which "does not have 3 clear days or 3 feet of level land". The rain fell in torrents all along the route. After a trip of 13 hours, I finally arrived in Xingyi, the seat of the autonomous prefecture government for Southwest Guizhou Autonomous Prefecture. This is the location of the Ministry of Energy Resources' Central Tianshengqiao Hydropower Statyioin.

Deputy director Tong Mingjie [4547 2494 2638] of the Central Hydropower station gave me a detailed introduction to the relevant background for this project to "transmit power from west China to east China": Based on the needs for developing the national economy in

Guizhou, Guangxi, and Guangdong, average yearly power output in these two provinces and one autonomous region will increase at a rate of 7 percent from 1985 to 2000 and the demand for power cannot be met by adding more thermal power plants. Moreover, most regions of Guangdong with rather good hydropower resources have already been developed, and it has a shortage of coal resources. The electric power shortage has become a primary factor restricting development of Guangdong's economy. Still, developing the abundant hydropower resources of the Hongshui He basin in the upper reaches of the Xi Jiang water system that flows through Yunnan and Guizhou provinces and Guangxi Zhuang Autonomous Region to achieve the "transmission of power from west China to east China", would basically solve the problem of the electric power shortage in the south China and Guizhou regions. Thus, this magnificent project has obvious economic and strategic significance for improving the energy supply structure in south China.

The Nanpan Jiang originates at the foot of Maxiong Shan in southeast Yunnan's Zhanyi County and flows through Shuangjiangkou [Dual River Mouths] at Wangmo in Guizhou and after joining the Beipan Jiang it enters Guangxi and is known as the Hongshui He. Its total length is 1,050 kilometers. The entire river basin is located in a subtropical zone with a warm climate and plenty of rain. The river flows at an average annual flow rate of 651 m<sup>3</sup>/second, which is 2.86 times that of the Huang He. The total head of 760 meters contains abundant hydropower resources that make it China's third largest hydropower base area after the upper reaches of the Huang He and the middle and upper reaches of the Chang Jiang. Especially noteworthy is the 14.5-kilometer-long Leigong rapids in Tianshengqiao Gorge at the boundary between Anlong in Guizhou and Longlin in Guangxi. This area has sheer cliffs, many shoals, and a fierce current and the river water with a head of 181 meters surges through waterfalls in the gorges. It is a "golden river section" greatly admired by countless Chinese and foreign hydropower experts and a hydropower "motherlode" that is seldom seen in China's famous rivers.

From the 1960's to 1970's, the State Council and relevant departments prepared several river basin plans, all of which recommended that Tianshengqiao Hydropower Station be among the first group of projects developed in the Hongshui He basin. In 1981, the State Council formally approved a magnificent plan for building 10 cascade power stations with a total installed generating capacity of 11,120MW and yearly power output of 60.3 billion kWh in different periods and groups on the Hongshui He. In 1982, construction began at the Tianshengqiao Second Cascade Power Station, a key state project that was to be built with state investments and would supply 20 percent of its power to Guangdong after completion. In June 1986, with the Ministry of Energy Resources leading the way, Guangdong, Guangxi, Guizhou, and the State Energy Resource Investment Company made a joint investment for development. A contractual agreement was also reached concerning the Tianshengqiao First

Cascade Power Station in which Guangdong would provide 50 percent of the investment and receive 50 percent of the power. In November 1989, preparations for building the Tianshengqiao First Cascade Hydropower Station got under way. Construction also began in late 1989 on the 981-kilometer-long 500 kV UHV power transmission and transformation circuit project running from Tianshengqiao to Guangzhou that was to be built simultaneously with the hydropower station.

## II. A World-Class Project

In the spring of 1982, Tianshengqiao Gorge, undisturbed for 1,000 years, seethed with excitement. Part of the construction staff from the Ninth Engineering Bureau of the Ministry of Water Resources and Electric Power which had gained victory in numerous construction battles in developing Guizhou's Maotiao He Cascade Power Station entered Tianshengqiao. [passage omitted]

The road from the Tianshengqiao main hydropower station at Xingyi in Guizhou to the hydropower station construction site at Longlin in Guangxi is 70 kilometers long. The Japanese-made (Yueye) automobile carried us rather quickly through the mountains where we could only see the hydropower station construction site 60 square kilometers in area. The simple sheds and footpaths built during the year when the construction staff had just arrived have been replaced by permanent structures with concrete frames and by concrete and asphalt roads totalling 443 kilometers in length. [passage omitted]

According to the design, Tianshengqiao hydropower station will include two cascade power stations for the first cascade (Dawan) and second cascade (Basuo). Preparations for construction of the second cascade power station were made from 1982 to 1984 and construction of the main part of the project began after March 1985, so construction has been going on for 9 years now. This is a large run-of-river hydropower project to utilize the enormous 181-meter natural head of Leigong Rapids. A 470-meter-long and 58.7-meter-tall concrete gravity dam will be built in Basuo He Gorge at the head of the rapids and three horizontal intake tunnels ranging from 8.7 to 10.8 meters in width and 9.5 to 9.8 kilometers in length will be built behind the dam and will pierce the center of the mountain at depths of 500 to 800 meters and run directly into the power generating station at the tail of the rapids. The current from the high head will pass through three enormous pressure regulation wells and the thrust will directly drive six large generators with a single unit installed generating capacity of 220 MW each. The installed generating capacity of the first phase of the project now under construction will be 880 MW and will generate an average of 4.92 billion kWh of power annually. When the Tianshengqiao First Cascade Hydropower Station upstream is completed, another 440 MW in installed generating capacity will be added to

raise the total installed generating capacity to 1,320 MW and average yearly power output to 8.8 billion kWh. [passage omitted]

The three underground intake tunnels that run for a total length of nearly 30 kilometers will involve the excavation of more than 3.6 million cubic meters of earth and rock. If it was arranged in a row 1 meter square, it would reach all the way from Guangzhou to Harbin. Moreover, the tunnels will pass through an ancient limestone and sandy shale zone on the Yunnan-Guizhou Plateau where karst has intensely developed. There are many variations in terrain which presented a succession of setbacks as soon as excavation began. Concealed in the mountains were karst caves with dangerous intersecting rocks, fractured zones, and ancient hidden rivers filled with silt, as well as rock explosions in deep strata created by the release of stress. [passage omitted] When there was a heavy rain at the surface the current rolled through the caves. During a 1-month period from 25 May to 25 June, it rained for a total of 20 days. At the construction site, I entered the caves twice with the Japanese experts and both times we were forced back out because of water flowing through the caves. The experts said that there were no prior examples in the history of hydropower construction for this type of tunnel excavation project where they were deeply buried, ran for long distances, had large tunnel diameters, terrible geological conditions, and various other difficulties in China or foreign countries at this time.

Xu Shuli [6079 6615 4409], senior engineer in the Technical Office of the People's Armed Police First Hydropower Brigade, vividly described the many dangerous sights during this fierce battle: on 20 Jul 85, when the big 10.8-meter diameter full cross-section tunnelling machine imported from the United States reached the 0+619 meter location on the No 2 main tunnel, an enormous current of mud and rock suddenly appeared. The 1,600-ton tunnelling machine groaned several times and was forced to a stop. The three teams responsible for the construction tasks sent four companies of troops to clear the debris. The fighters bared their shoulders and bent their waists and used only their two hands to clear away 13,000 cubic meters of mud. Still, as soon as they had finished removing the old flow of mud and rock, a new flood surged out! Originally, they actually were fighting the entire muddy battle in the upper reaches of a hidden river. Hydropower and geology experts arrived from Beijing and after doing some research, they adopted construction measures for "blocking first and clearing later". They were able to cross the ancient buried river only after working for nearly half a year. A year later, however, as a thunderstorm was in progress, a big landslide occurred in the old karst cave and the "mud dragon" returned. In this way, they spent 201 days altogether before they able to subdue this "tiger blocking the way". With this going on underground, a war against landslides was underway at the surface. At the plant building, which was the tail-end of the main battle, excavation of the high slope at the site of the pressure regulation wells required the cutting of a huge mountain rising 340 meters above the river surface with 50°

slopes and fragmented and fractured rock strata to make 9 huge terraces. Just after they had excavated and removed several hundred thousand cubic meters of earth and rock, detectors discovered in January 1987 that a 1.2 million cubic meter landslide body on the upper part of the high slope was moving at a rate of 9mm a day and the outcome would not be hard to imagine when the rainy season arrived. This hazard frightened Chinese and foreign geology experts and four changes were made in the station site as a result. After adopting various measures like load reduction, driving anti-slip piles and prestressed bolts, and so on, they finally subdued this hazard. The horrible geological conditions during construction of Tianshengqiao forced Japan's (Dacheng) Company, which originally had planned to assume contractual responsibility for part of the underground engineering and had gained considerable fame during construction of Lubuge Hydropower Station in Yunnan, to sound the retreat. State Council Premier Li Peng arrived here in November 1986 while the flow in the large river was being cut off for Tianshengqiao to make an inspection and he encouraged the fighters: if they can build Tianshengqiao, there would be no technical problems at other hydropower station projects. According to statistics, since construction of the main part of the project for the second cascade power station began in March 1985, they had encountered 553 big and small karst caves in the intake tunnel project alone and a total of 804 days were spent in dealing with the karst caves, cave-ins, water surges, rock explosions, and other bad geological situations!

In the Engineering Department Office of the People's Armed Police First Hydropower Brigade, department director He Zhenxiang [0149 4176 4382] pointed to a project progress chart on the wall and told me that now, after several years of bloody struggle, we have made significant advances in construction. By the end of May 1990, the three intake tunnel projects, a main factor affecting the construction schedule of the power station, had completed a total excavation driving footage of 19.6 kilometers, including the No 1 main tunnel where only 1,794.7 meters remains and the No 2 main tunnel where only 3,250 meters remains. Most of the large dam has been poured to the top. Although there were many work procedures in the station building project and much intersecting work, installation of some of the main machinery may begin in July 1990. The two construction staffs are now advancing victoriously and fighting for power generation at the second cascade power station in 1991.

### III. Especially Enticing Prospects

After gaining an understanding of progress in construction of the Tianshengqiao Second Cascade Power Station, I also went to the construction site for the first cascade power station. The 10 kV high-voltage lines used for construction that cross over the river are now being put into place. Bids have been solicited for the large

bridge over the river in the area of the large dam and the temporary vehicle ferry or they are now under construction. The construction charts and budgets for the design for the highway running from Xingyi to the power station that will be used by power plant employees when they come to and leave work will be ready in August. In the future, at a site 7 kilometers upstream from the second cascade power station, the 178 meter tall and 1,137 meter long faced stone-fill dam, the largest in the world at the present time, will rise up from the ground. The dam will store 10.8 billion cubic meters of water and will form a high gorge lake with a backwater over 100 kilometers long on the Nanpan Jiang. After it goes into operation, the Tianshengqiao Second Cascade Hydropower Station will have a total installed generating capacity of 2,520MW and will generate an average of 14.18 billion kWh of power annually, making it China's second largest hydropower station with power output that is about the same as Gezhouba. At the same time, an investment and power share program for Guangxi's Longtan Hydropower Station, the largest in scale on the Hongshui He with a total installed generating capacity of 4,200 MW and average yearly power output of 18.7 billion kWh developed through joint investments will be approved in July 1990, and this project will get underway soon.

Japan, the United States, Sweden, and other countries that were attracted by the enormous economic benefits that will be created after development of the Hongshui He have come to inspect the construction site several times in the past few years and the Japanese government has also provided a low-interest loan. The leaders at Tianshengqiao Hydropower Station wanted me to tell all the relevant provinces that their biggest problem now is a shortage of capital and they hope that the investments that all of the provinces had originally decided upon will be allocated to the power station as quickly as possible so that the Hongshui He will be able to provide light and heat to all the provinces as quickly as possible.

### **Pumped-Storage Station To Be Built in Anji**

906B0099D Shanghai WEN HUI BAO in Chinese  
9 Jun 90 p 9

[Article by reporter Shen Ding [3088 1353]: "Large Pumped-Storage Power Station To Be Built at Anji, County Government Economic Delegation Arrives in Shanghai Seeking Cooperation"]

[Text] At the Anji-Shanghai 1990 Joint Friendship Meeting held today, bureau director Zhou Xianggen [0719 4382 2704] of the East China Power Management Bureau revealed that the Tianhuangping Pumped-Storage Power Station will be built in Anji County. It will have the largest scale in China and will be one of the largest in the world.

Zhou Xianggen indicated that the design installed generating capacity of this power station is 1,800 MW and

its main equipment will be imported from foreign countries. The total investment will be 2 billion yuan. Because of Anji's exceptionally advantageous terrain, no people will have to be resettled to construct the reservoir and the power generation head could be as much as 500 meters high. After this power station is completed, it will play a major role in safety and stability of the East China Grid and in economic development of the three provinces and one municipality in the east China region. A government economic delegation led by Anji County CPC Committee Secretary Wang Jin'gen [3769 6855 2704] and Anji County magistrate Hu Wei [5170 0251] is visiting Shanghai in search of even broader economic and technical cooperation with Shanghai.

### **Construction of Shuikou Hydropower Station Accelerated**

906B0099C Beijing RENMIN RIBAO in Chinese  
22 Jun 90 p 1

[Article by reporter Zhang Mingqing [1728 6900 3237]: "Construction of Shuikou Hydropower Station Accelerated, Reform the Management System, Raise Construction Levels"]

[Text] At the base pit site for Shuikou Hydropower Station, a key state project during the Seventh 5-Year Plan, one sees countless construction personnel on a work site the size of 30 soccer fields where over 10 drilling rigs, back diggers, and loaders are brandishing their iron arms and several dozen loaded trucks busily run back and forth. Everything is being done at a feverish pace as well as orderly and procedural.

The old generals from Shuikou Hydropower Station Company and Huatian Joint Venture Company, the business with contractual responsibility for the power station, told me that before reform, it took at least 10,000 people at the site for a big hydropower construction project with an installed generating capacity of 1,400 MW. Now, there are only about 1,500 management personnel and laborers from the business which has contractual responsibility for this project along with about 3,000 subcontracting personnel. Because of the limited number of construction personnel, the construction site has been able to drop the heavy burden of being a "little society". The area of temporary structures at Shuikou Hydropower Station is 35,000 square meters, just one-seventh the area required by traditional construction in the past. Because of the high degree of mechanization in construction, labor productivity is also high. During excavation of the open flow diversion canals, the highest monthly excavation amount was 320,000 m<sup>3</sup>. There is no comparable example in the history of hydropower construction in China.

The investment for Shuikou Hydropower Station was raised through many channels and some of it utilized a World Bank loan. Changes in the investment system required corresponding changes in the management system. As a

result, the Shuikou Hydropower Station Construction Company was established. Internally, it gave obligations to the construction units and externally it was the engineering unit engaged by the owner, Fujian Province Electric Power Bureau. According to contract stipulations, the Electric Power Construction Company carried out quality inspections, progress supervision, and expenditure control for the business with contractual responsibility and reported to the World Bank monthly and quarterly. At the same time, the experts engaged by the World Bank visited the site for strict inspections twice each year. Establishing these "antitheses" restricted the defects in construction units of marathon construction schedules and bottomless expenditures.

Reform of the management system and importing advanced equipment, technology, and management from foreign countries provided obvious benefits during the first phase of the project. From the time ground was broken to begin construction of Shuikou Hydropower Station on 9 Mar 87 until 25 Sep 89, blockage of the flow of the large river was accomplished ahead of schedule. In 2 and 1/2 years, they excavated 7 million m<sup>3</sup> of earth and rock, poured 300,000 m<sup>3</sup> of concrete, and put in place 1.8 million m<sup>3</sup> of structural fill, completing a total of more than 300 million yuan of the investment.

#### **Yarlung Zangbo Jiang Hydropower Resources Studied**

906B0099B Beijing KEJI RIBAO [SCIENCE AND TECHNOLOGY DAILY] in Chinese 5 Jul 90 p 1

[Article by Yu Fasheng [0827 4099 0524]: "Daguiwan He Segment of Yarlung Zangbo Jiang Extremely Rich in Hydropower Resources"]

[Text] The results of systematic research and appraisal by the relevant experts of the region within a circumference of 50,000 square kilometers around the Daguiwan He segment in the lower reaches of Yarlung Zangbo Jiang indicate that this region is an important strategic area with a hydropower motherlode in China and the site of rich concentrations of hydropower resources.

The installed generating capacity on this section of the river could be as much as 62,700 MW at a unit investment of 1,427 yuan per kW in capacity. Compared with the Three Gorges Project on the Chang Jiang, it would require just one-fourth of the investment for the Three Gorges Project and could obtain the capacity of 6.3 Three Gorges power stations.

This region has an extremely low population density and no major social, ecological, or economic questions such as large scale population resettlement, environmental pressures, and so on.

The results of comprehensive appraisal show that implementation of a "development in stages, using power to develop power" program to build this group of power stations is feasible in the social, economic, ecological, technical, and other areas. When it is completed, it will have enormous socioeconomic value and its ecological value will be inestimable. According to information provided by Wu Zufa [0702 4371 4099], president of the Chang Jiang Ecological Sciences Research Academy, completion of this research project indicates that mankind's understanding of this energy resource treasure-house is moving from a type of circular imagination toward scientific appraisal, which will provide a scientific basis for converting this glorious dream into an objective reality.

### **More Thermal Power Called for in Inner Mongolian Development Plan**

*916b0016A Beijing RENMIN RIBAO in Chinese  
3 Nov 90 p 1*

[Article by reporters Ao Teng [0277 7506] and Qu Zhenye [4234 2182 2814]]

[text] Hohhot 2 Nov—The reporters regarded a map hanging on the wall in the office of the leading cadre of the Nei Monggol Autonomous Region Government showing Nei Monggol stretched across the northern frontier of the country. Distributed over Nei Monggol were symbols for the locations of six major coal fields, and two very long lines connecting the oil fields from east to west, one a dedicated rail line for shipping coal, and the other a high voltage power line. The map depicted the future of the Nei Monggol energy industry. By the year 2,000, Nei Monggol coal output may reach 130.7 million metric tons, installed electric power capacity could be 15.07 million kilowatts (kW), and rail lines for shipping coal may reach a total length of 1903 kilometers (km).

Nei Monggol coal resources are extremely bountiful, with proven reserves of 217 billion metric tons, about 1/4 that of the whole country, but up to this year coal production volume has been less than 40 million tons. As the national coal development strategy moves westward and construction of several open-pit mines are pushed ahead, it is expected that the Nei Monggol coal industry will double in 5 years, and in 10 years it will have increased by three times.

As coal production volume is doubled and redoubled, it will create excellent conditions for electric power development. In the next 10 years, the installed capacity of the entire region will increase 11.65 million kW, about 3.4 times that of total installed capacity throughout 41 years of reconstruction.

Construction and operation of large generators and large power plants will set the stage for energy transformation of Nei Monggol. It is believed that by the end of the Ninth 5-Year Plan the entire region will provide for outside provinces an installed capacity of 9.1 million kW. One power distribution engineering feasibility study already concludes that by then the east-west portion of the trans-Nei Monggol power network will become the hub of China's northern tri-regional network.

Focusing on the energy industry, especially electric power, as key to the strategy for accelerated development of the region, Nei Monggol, with the support of the central government, approved guarantees for actuating the power industry, adopted various forms of funding, granted preferential cost and tax advantages, and secured a financial base for electric power construction. Subordinate elements of the Autonomous Region Power Administrative Bureau have already raised 2.1587 billion yuan of the 2.9513 billion needed for the Eight 5-Year Plan, and now may proceed with organization and construction as planned.

### **Shanxi's Progress in Power Plant Construction Recapped**

*916b0016B Taiyuan SHANXI RIBAO in Chinese  
5 Sep 90 p 1*

[Article by reporters Ren Weila [0117 1792 2139] and Lei Jiande [7191 1696 1795]]

[Text] Major national energy projects undertaken by Shanxi's 17,000 power construction staff and workers during the Seventh 5-Year plan include the Shentou No 1 Power Plant, Zhangze Power Plant, Taiyuan No 1 Power Plant, Shentou No 2 Power Plant, and the Yongji and Shalingzi power plants. During this period they have raised a capital construction investment of 4.4 billion yuan, and have added 1.65 million kW of installed capacity and 1,276 km of transmission lines of 220 kilovolts and above, an increase of 32 percent and 17 percent, respectively, over that of the Sixth 5-Year Plan.

This year is the last year of the National Seventh 5-Year Plan, and it is the biggest year in Shanxi's history for start-up electric power production. Included in five large- and medium-scale power engineering projects, in and about the province, undertaken by Shanxi workers, are five power units of a total capacity of 1.07 million kW for which every effort is being made to meet commitments and secure investments within the year. Facing difficult engineering challenges under stringent time and funding constraints, the Provincial Electric Power Bureau pressed into the field a cooperative effort of work teams composed of able cadre, technicians and professionals, under direction of the Bureau leadership. The mass of workers overcame every sort of difficulty under demands for quality, speed, and results, worked in the field night and day, set records in output, met national acceptance standards on every project, and assured key project goals ahead of schedule.

**Oil Fields Strive To Meet Targets**

40100015A Beijing CHINA DAILY (Economics and Business) in English 2 Nov 90 p 2

[Text] (XINHUA)—Managers of China's major oil fields are busily engaged in taking various measures to guarantee the fulfillment of the State targets for crude oil production.

The Daqing oil field—the largest of its kind in China—has managed to steadily increase its output by speeding the pace of placing new oil wells into production and by strengthening its management of mechanical oil production.

According to an official of the oil field, it will have no problem in fulfilling its target of 55.6 million tons of crude oil by the end of this year.

In the first half of October, the Dagang oil field succeeded in increasing its daily output to 10,620 tons, an increase of 327 tons over that of last month.

The Liaohe oil field increased its daily output to 37,600 tons this month, an increase of 500 tons. The oil field is expected to not only fulfil its target of 13.5 million tons, but to produce an additional 100,000 tons.

The "Bao-1" oil well in the Kailu basin in the eastern part of the Inner Mongolia Autonomous Region has produced oil flows, identifying new oil reserves for the Liaohe oil field.

In the past three years, a dozen prospect wells have been drilled in the 32,300 square kilometre Kailu basin and have resulted in oil flows.

The "Bao-1" well has been verified to have 27 oil-bearing layers with a total thickness of 87.2 metres. It can produce 20.4 cubic metres of crude oil and about 800 cubic metres of natural gas daily.

With convenient transportation and communications conditions, the oil resources in the region can be easily extracted.

**Big Oil, Gas Deposit Found in Northwest**

40100016A Beijing CHINA DAILY in English 30 Nov 90 p 1

[Article by staff reporter Xu Yuanchao]

[Text] Large gas and oil deposits have been discovered in Northwest China, an oil industry official said yesterday.

Wang Tao, general manager of the China National Oil and Gas Corporation, told CHINA DAILY that the output of the gas field, discovered in the Shaanxi-Gansu-Ningxia Basin, would surpass that of Sichuan and become the country's top natural gas producer.

Sichuan is now China's major gas producer, turning out nearly half of the country's natural gas. Its output is expected to reach 6.5 billion cubic metres this year.

Wang said the new gas-bearing area covers 10 counties in Shaanxi and Gansu provinces and Ningxia and Inner Mongolia autonomous regions.

Since 1986, the Changqing Oil Exploration Bureau has drilled 43 gas wells in the area, 12 of which have been tested to each produce over 200,000 cubic metres of natural gas daily.

"We think the amount of gas reserves in the area will be higher than those found in Sichuan," he said.

The general manager said the biggest wells are located in Jinbian County and Yulin Prefecture in Shaanxi Province. The area, covering 1,200 square kilometres, contains rich natural gas reserves.

"We have asked Changqing Bureau to step up efforts to discover at least 20 billion cubic metres of gas reserves," he said.

Experts estimate the gas reserves in the basin may reach 100 billion cubic metres.



### Experts Trying To Solve Problems at Qinshan

40100018 Beijing CHINA DAILY in English  
21 Nov 90 p 1

[Article by staff reporter Li Hong]

[Text] China's top nuclear power experts are trying to solve the remaining technical problems at the country's first nuclear power station before it enters the commissioning phase.

If not resolved in time, said a senior official from the National Nuclear Safety Administration (NNSA) in Beijing, they could "hold back the Qinshan Nuclear Power Corporation from getting the certificate for loading nuclear fuel."

NNSA, to which the 29-member nuclear safety experts committee serves as an advisory body is an independent government nuclear regulatory organization empowered to enforce strict surveillance and verify the safety of all nuclear plants set up in the country.

The official said it was hard to predict when China's first self-designed and self-built nuclear plant will start operating and be linked to the national power grid.

But efforts are being made to complete all test work and start loading the first reactor with nuclear fuel sometime next year.

Qinshan is scheduled for completion during the Seventh Five-Year Plan period (1985-90).

However, the fact that much of its key equipment was made and installed "before NNSA started operation in 1984 and in the absence of State nuclear safety principles," has caused trouble in the construction of the Qinshan project, experts claimed.

### Treatment and Disposal of Tritiated Water

906B0101 Chengdu HE DONGLI GONGCHENG  
[NUCLEAR POWER ENGINEERING] in Chinese  
Vol 11, No 3, 10 Jun 90 pp 86-89

[Article by Xu Lihua [6079 0448 5478] of the Southwest China Reactor Engineering Research and Design Institute: "Treatment and Disposal of Waste Water Containing Tritium"]

[Text] This article describes the characteristics of tritium, methods for treating and disposing of waste water containing tritium, and disposal of waste water containing tritium from China's high-flux engineering test reactor (HFETR).

Key words: waste water containing tritium, disposal, dilution, release, HFETR

#### I. Introduction

With the rapid growth of the atomic energy industry and the continual increase in the number and power of

nuclear power plants and reactors, experiments with nuclear weapons and thermonuclear weapons, and especially the development of research work on fusion reactors, there have been substantial increases in the release of tritium. As a result, treatment and disposal of waste materials containing tritium have become essential.

Tritium ( $^3\text{H}$ ) is hydrogen's heaviest and only radioactive isotope. It exists 99 percent as tritiated water (HTO) and 1 percent as tritiated hydrogen gas (HT). Moreover, the physical and chemical properties of tritiated water are extremely similar to common water, so it is extremely hard to separate from water.

#### II. Disposal of Waste Water Containing Tritium

##### 1. Atmospheric release

The method in which waste water containing tritium is converted into steam and discharged via tall smokestacks into the atmosphere has been the subject of considerable debate in the past several years, and it is one of the methods actually in use. This method is feasible for atomic energy research institutes or plants which do not have rivers, lakes, or seas for dilution and releasing.

France has developed a blast evaporation method to treat waste water containing tritium. Its CMAP plant uses this method to treat waste water containing tritium with an original tritium concentration of 52 MBq/L and has a processing capacity of 50 L/h. The tritium concentration released into the atmosphere is lower than the permissible concentration of tritium in the air, which is 7.4 Bq/L. Consideration must be given to the geographic environment, climatic conditions, population and residential density, height of the release port, environmental dilution factors, and other factors when using this method to dispose of waste water containing tritium, and special attention must be given to preventing concentrated settling of tritium within the local area.

##### 2. River dilution and release

River dilution and release is one of the most important ways to dispose of waste water containing tritium at the present time. During river dilution and release, to achieve rapid homogeneous mixing of the waste water containing tritium with the river water, the release is often done during flood peak periods or in river sections with rapid currents.

From 1950 to 1970, the 10 MWe heavy-water reactor at the Australian Atomic Energy Research Institute discharged about  $10 \times 10^3$  m of waste water containing tritium into the (Wulun) River with a tritium content of  $11 \times 10^4$  MBq and a maximum of  $3.7 \times 10^8$  MBq. The tritium concentration in the riverwater was 11 kBq/L. The [United States] Hanford Special Plant discharged  $1.6 \times 10^8$  MBq of tritium into the Columbia River in 1970 and the maximum concentration of tritium in this river was 9.2 kBq/L.

### 3. Marine dilution and release

Marine dilution and release is an important way to dispose of waste water containing tritium in many countries, especially coastal nations. Vast seas provide favorable conditions for diluting and releasing waste water containing tritium. The waste water containing tritium released into the sea mixes with seawater on the sea surface and is gradually dispersed downward. The tritium in seawater is usually distributed in relatively warm shallow water layers called mixed layers at 50 to 100 meters. The tritium remains in the 75 meter mixed layer for about 22 years. This method of releasing waste water containing tritium does not require consideration of the effects of biological concentration and is conducive to dilution and dispersal of tritium. Sehnez and others feel that slowly releasing tritium ( $<7.4 \times 10^4$  MBq/L) from a ship into the wake at the tail of the ship produces very satisfactory results. Many European nations like England, France, and Holland as well as Asian countries like Japan use favorable natural conditions for marine dilution and release and many of their nuclear facilities are built along their coasts.

### 4. Deep well disposal

Deep well disposal of waste water containing tritium is another rather widely used method. Underground nuclear explosion shafts or abandoned oil wells can be used to treat waste water containing tritium in geological rock strata. An evacuated abandoned oil well near West Germany's Karlsruhe Nuclear Research Center has been used to dispose of waste water containing tritium by pressure injection into the abandoned well since 1973. In selecting abandoned oil wells for disposing of waste water containing tritium, consideration must be given to: 1) Ensuring separation from major water bodies; 2) The amount of tritiated water injected must not exceed the amount of crude oil extracted from the oil well to avoid changing the original geological conditions; 3) When oil is still being extracted from other oil wells near the selected abandoned oil well, corresponding monitoring measures are needed to detect any possible migration of waste water containing tritium toward other oil-bearing strata that might appear.

### 5. Other disposal methods

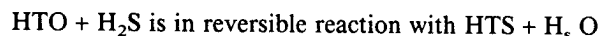
Besides the more common disposal methods described above, foreign countries also use osmosis tanks, hydraulic fracturing, freezing, and other methods for disposal. Some articles also suggest concentrating liquid tritium to carry out various solidification treatments<sup>[1]</sup>.

## III. Treatment of Waste Water Containing Tritium

Most treatment methods for waste water containing tritium are in the research and experiment stage and very few have actually been placed into plant-scale production.

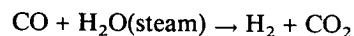
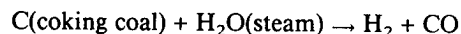
### 1. Dual-temperature exchange

Dual-temperature exchange involves placing waste water containing tritium and a gas into countercurrent contact in towers having two different temperatures and using an exchange reaction between hydrogen isotopes to make the tritium concentration in the water greater than the tritium concentration in the gas and thereby attaining the goal of concentrating the tritium. The gases that can be used include  $\text{NH}_3$ ,  $\text{H}_2\text{S}$ ,  $\text{HCl}$ ,  $\text{HBr}$ ,  $\text{H}_2$ , and so on, but the separation coefficient of  $\text{NH}_3$  is rather low and  $\text{H}_2$  requires the use of a catalyst. Although  $\text{HCl}$  and  $\text{HBr}$  gas have larger separation coefficients, they are relatively corrosive. Usually, it is best to use  $\text{H}_2\text{S}$  since it has a large separation coefficient, small corrosive effects, can treat large amounts, low cost, and other advantages, so it is the gas with the best prospects. The exchange reaction when using  $\text{H}_2\text{S}$  is:



### 2. Low-temperature distillation

Low-temperature distillation involves first using water and coal gas to convert tritiated water into tritium gas, cooling the tritium to a low temperature, liquefying, and then distilling it, and thus concentrating and separating out the tritium. The process reaction formula is:



Low-temperature distillation at normal pressures requires cooling to about  $-250^\circ\text{C}$  and the separation coefficient may be as large as 2 to 3. Moreover, there is no corrosiveness, but the disadvantage is the relative difficulty of handling large amounts of liquid hydrogen.

### 3. Thermal diffusion

The thermal diffusion method uses a hydrogen isotope mixture to separate the tritium in a narrow circular space using different thermal diffusion characteristics. Thermal diffusion columns are structurally simple and easy to operate. The disadvantage is a small separation coefficient and high energy consumption. Some laboratories now use this method to concentrate tritium. Verhagen installed two diffusion columns and one container in 1967 and concentrated it 10 times over 20 hours with a tritium recovery rate of 95 percent. A few years ago, Japan also did some successful research work in this area in the laboratory.

### 4. Electrolysis

The electrolysis method separates and concentrates tritium by using the principle of electrolysis of light water being easier than tritiated water. This method has a large separation coefficient but consumes much energy. It is usually used to re-enrich heavy water and concentrate small volumes of tritium. Bagan and others used an acid electrolysis method in 1973. The speed of electrolysis was great and the multiplication factor of the tritium concentration was also large<sup>[2]</sup>.

There are many other ways to treat waste water containing tritium, including gas-solid chromatographic separation, solvent extraction, osmosis film separation, and so on. However, most of these methods are still in

the laboratory research stage and have not yet been used in industrial scale production. Table 1 provides a comparison of the various methods used to treat waste water containing tritium.

Table 1. Comparison of Methods for Concentrating Waste Water Containing Tritium<sup>[3]</sup>

Separation method	Separation principles	Estimated expense, \$/L	Advantages	Disadvantages
Dual-temperature exchange	Water and hydrogen sulfide gas are placed into countercurrent contact in two towers having different temperatures	0.026-0.052	Relatively large separation coefficient, can treat large amounts, low cost	H <sub>2</sub> S is toxic and highly corrosive, process control is difficult
Distillation	Differences in the boiling points or volatility of the isotope molecules of liquid hydrogen or water are used for concentration	0.052-0.105		
Low-temperature distillation	After converting tritiated water into hydrogen isotopes, it is distilled at low temperatures below -250° C	0.079-0.158	Large separation coefficient	Large amounts of liquid hydrogen, complex operations
High-temperature vacuum distillation	Tritiated water is boiled and distilled under vacuum conditions		Simple operations	Small separation coefficient, high energy consumption
Chromatographic separation	Certain materials are used for selective adsorption of tritium isotopes		Simple operations	Requires conversion to tritium gas, treats relatively small amounts
Lithium	Stronger adsorption of hydrogen isotopes using lithium plates	>6.600	Large separation coefficient	Expensive equipment
Zeolite	Stronger adsorption of heavy isotopes using artificial zeolite	>0.260	Low equipment expense	Rather small separation coefficient
Thermal diffusion	Hydrogen isotopes enter ring-shaped equipment with a hot wall in the center and cool wall around the periphery and separation is carried out on the basis of thermal diffusion principles	>0.792	Simple design and operations	Extremely small separation coefficient, high energy consumption, small treatment amounts
Electrolysis	Tritiated water is placed in a water electrolysis and concentration electrolysis tank	>0.260	Large separation coefficient	High energy consumption, treats small amounts
Solvent extraction	Organic ions are used for selective extraction of tritiated water and the tritiated water is then recovered by evaporation	>0.260	Simple operations	Small separation coefficient, expensive equipment

#### IV. Disposal of Waste Water Containing Tritium from China's HFETR

The main source of tritiated water from China's HFETR is the tritium generated by leakage from the cladding of fuel rods into the primary loop coolant.

##### 1. Geographical environment of the HFETR

Our HFETR is located in a mountainous region of southwest China behind the Emei Shan tourism region on the bank of the Qingyi Jiang. The population is relatively dense and there is quite a bit of fog and rain

during the year. The minimum average yearly flow rate of the Qingyi Jiang is 92 m<sup>3</sup>/s and the maximum average yearly flow rate is 10,000 m<sup>3</sup>/s. The HFETR has a 125 meter tall smokestack and the atmospheric dilution factor is <10<sup>-6</sup> s/m<sup>3</sup> [4].

##### 2. Disposal methods

a. Atmospheric dilution and discharge. The tritiated water is evaporated and converted into tritium gas and released from the 125 meter tall smokestack. The tritium concentration in the air is <10<sup>-2</sup> Bq/L, below the state-permitted standard, so it is safe and reliable. However,

converting tritiated water into tritium gas is much less economical than using the Qingyi Jiang for dilution and release. Moreover, when the released tritium vapor encounters bad weather or is released over long periods, it is possible for the tritium to be concentrated in the local area.

b. Dilution and release in the Qingyi Jiang. In using the Qingyi Jiang for dilution and release, the  $< 18.5$  kBq/L waste water containing tritium is released at a flow rate of  $45 \text{ m}^3/\text{h}$  ( $0.0125 \text{ m}^3/\text{s}$ ) into the Qingyi Jiang (total radioactive  $B < 10 \text{ Bq/L}$ ). Because the minimum and maximum average yearly flow rates of the Qingyi Jiang are known, the minimum dilution capacity of the Qingyi Jiang is  $7.3 \times 10^3$  times and the maximum dilution capacity is  $8 \times 10^5$  times. The minimum tritium concentration in the water of the Qingyi Jiang is  $2.31 \times 10^{-2} \text{ Bq/L}$  and the maximum tritium concentration is  $< 2.53 \text{ Bq/L}$ , lower than the state-permitted concentration standard of  $11.1 \text{ Bq/L}$  for tritium in open water sources. Sample measurements taken 100 m from the point of release into the Qingyi Jiang showed that the tritium concentration was not much greater than the concentration in natural water. Practice over several years has proven that using the Qingyi Jiang to dilute and release waste water containing tritium from the high-flux engineering test reactor is economical, safe, and feasible.

#### V. Conclusion

To dispose of waste water containing tritium, an economical, safe, and feasible method of disposal should be chosen according to the geography, natural environment, and other

concrete conditions of each unit. For example, in northern China, which has limited rainfall and dry air, especially vast northwest China, atmospheric release and natural evaporation can be used. South China, which is mountainous, has many rivers, and significant dilution by natural water, dilution and release into rivers and lakes can be used. Along the coast, the sea can be used for dilution and release to dispose of waste water containing tritium. However, treatment of waste water containing tritium is still in the research and exploration stage, and the experience and technology is extremely immature, so there must be further research, development, and perfection.

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## Distribution and Types of Geothermal Resources in China

906B0094 *Chongqing XIN NENGYUAN [NEW ENERGY SOURCES] in Chinese*  
Vol 12, No 6, 5 Jun 90 pp 32-41

[Article by Wang Jun [3769 6874] and Wang Ji'an [3076 6549 1344] of the Chinese Academy of Sciences Geology Institute]

### [Text] Abstract

Based on the ground temperature and distributional characteristics of China's hot springs, this article discusses the distribution and types of geothermal resources in China and divides them into geothermal resource distribution regions with visible and concealed geothermal resources. On the basis of analysis of the ground temperature distribution and geological structures, it differentiates the types of geothermal resources, which is very important for understanding the characteristics of China's geothermal resources and for planning the prospects for development and utilization.

Geothermal resources have attracted world attention as a new energy resource, especially since the world energy crisis of the 1970's, when there was rapid growth in the development and utilization of geothermal resources, and they now account for a substantial proportion of total energy resources in some countries.

China was concerned with the development and utilization of geothermal resources several 1,000 years ago. After the birth of New China, and particularly since the 1970's, survey research and work to develop and utilize geothermal resources in China entered a new stage. In reviewing the history of geothermal resources surveys, exploration, development, and utilization in China over the past 20 years, although it underwent several rises and falls, there is now a more stable and broad-based foundation for work to develop and utilize geothermal resources. In conjunction with the distributional characteristics of China's geothermal resources, we also have a clearer understanding of the direction for developing and utilizing them. Undoubtedly, this will play an important guiding role in planning for the prospects of geothermal resource surveys, development, and utilization in China.

### I. The Distribution of China's Geothermal Resources

Hot springs and buried hot groundwater can be found in all provinces and autonomous regions in China and we are extremely rich in geothermal resources. Geological structures play a controlling role in the distribution of geothermal resources. Many geothermal regions are located in zones where the crust is rather thin, which are usually zones that have experienced intense tectonic activity since the Mesozoic and where there are deep fractures and mantle fracturing. Most hot springs and concealed geothermal regions are located in these areas. As a result, these zones are the richest in geothermal resources.

China's hot groundwater in geothermal regions can be classified into three grades according to its temperature characteristics: 1) 25 to 60° C are low-temperature geothermal regions (hot springs); 2) 60 to 100° C are moderate-temperature geothermal regions; 3) 100 to 150° C are high-temperature geothermal regions. The corresponding hot springs are divided into low, moderate, and high-temperature hot springs.

This shows that China's high-temperature geothermal regions are mainly located in a zone along the east coast that includes Taiwan and in the Tibet-Yunnan area of southwest China. They are all located along the margins of plate structures and are part of the Mediterranean Sea geothermal zone and the Pacific Ocean geothermal zone. Most of China's geothermal regions are primarily moderate and low-temperature ones and are located in the zones of intersection of large and small fault blocks and Mesozoic-Cenozoic sedimentary basins formed by fault subsidences or subsidences within China's boundaries. The regions can be classified into geothermal regions with obvious ground surface geothermal indications and concealed sedimentary basin geothermal regions according to the depth of burial, outcropping, and other conditions.

#### A. Regions where geothermal resources with visible geothermal indications are distributed

This category of geothermal resources are found mainly in uplifted mountainous regions and in hilly or valley areas. Most of China's geothermal indications are moderate and low-temperature hot springs, while our gas orifices, boiling springs, geysers, and other intense high-temperature geothermal indications are mainly located in high-temperature geothermal regions like Taiwan and the Tibet-Yunnan region. According to incomplete statistics, China now has over 2,500 hot springs. As surveys of geothermal resources become more extensive, the number of hot springs will also increase. However, the distributional characteristics, water temperatures, water quality, and other conditions of these 2,500-plus hot springs basically reflect the preservation conditions and outcropping characteristics of geothermal resources in China's uplifted mountainous regions. China can be divided into several hot spring concentration zones based on the temperature of the hot springs and the density of their distribution: 1) The Tibet-Yunnan high-temperature hot spring concentration zone; 2) The southeast coast and Taiwan moderate and high-temperature hot spring concentration zone; 3) The Jiaoliao moderate and low-temperature hot spring concentration zone; 4) The north and south Sichuan-Yunnan moderate and low-temperature hot spring concentration zone; 5) The Fenwei-Zhangbei moderate and low-temperature hot spring concentration zone. Besides these, there are also several smaller scale hot spring concentration zones located on the boundary fractures of the many fault blocks that form the Chinese mainland. The temperature of the moderate and high-temperatures ranges from 60 to 150° C, while the temperature of the moderate and low-temperatures ranges from 25 to 100° C.

1. The Tibet-Yunnan moderate and high-temperature hot spring concentration zone. This is located on China's southwestern frontier along both sides of the Yarlung Zangbo Jiang in southern Tibet and eastward into the Three Rivers region and from western Yunnan turning southward through Tengchong and on south into Burma. The zone contains more than 700 hot springs, most with temperatures from 70 to 90° C and the highest at up to 100° C. Several wells drilled in the hot spring region show that 150 to 170° C hot groundwater and moist steam can be obtained at 10 to 150 meters below ground. The famous Yangbajing geothermal field in Tibet and the Rehai ["Hot Sea"] geothermal field at Tengchong in Yunnan are both located in this zone.

It should be pointed out that there are several 10 high-temperature hot springs with temperatures in excess of the local boiling points located in the high mountains and deep valleys of the Three Rivers region turning southward from Tibet that are distributed along the eastern margin of the Tibet Plateau. They indicate the possible existence of a branch extending northward in the moderate and high-temperature hot spring concentration zone of Tibet and Yunnan. This point provides important information for understanding the distributional characteristics of geothermal resources in southwest China.

2. The moderate and high-temperature hot spring concentration zone along the southeast coast and on Taiwan. This zone is part of the geothermal zone around the Pacific Ocean. The Hualian rift valley on the eastern part of Taiwan Island is a collision zone between the Pacific Ocean plate and the Eurasian plate. The Datun volcano cluster and Jilong volcano group at the northern end of the island has gas orifices (120° C) and wells (300 to 1,500 meters, 294° C) with the highest temperatures in China. The island has over 90 hot springs including the Qingshui-Tuchang, Macao, Dahuangzui, Lushan, and other geothermal regions and hot groundwater and moist steam at over 180° C can be obtained at depths of 1,000 to 2,000 meters below ground.

In the zone in Fujian, Guangdong, eastern Jiangxi, and southern Hunan along the southeast coast of China, there are over 600 hot springs, most with temperatures of 40 to 80° C, and there are 10 sites with temperatures in excess of 80° C. Hot groundwater at over 100° C has also been obtained at depths of 100 to 1,000 meters at Zhangzhou, Shantou, Fuzhou, Yangjiang, and other locations. A geyser was also discovered during drilling recently at Zhangzhou (it has now ceased erupting), which indicates that this region contains rich reserves of geothermal resources.

The geothermal indications of these two moderate and high-temperature hot spring concentration zones can be compared favorably with several famous geothermal regions of the world. Excluding the highly acidic water quality from some of the wells in the Macao geothermal field and Dahuangzui geothermal field (on Taiwan), and Rehai geothermal field (in Yunnan) (pH of 2.4 to 6.0) and are highly

corrosive, the water from most of the hot springs has a salt content of 1 to 3 grams/liter and it is  $\text{HCO}_3\text{-Cl-Na(Ca)-Mg}$  or  $\text{Cl-HCO}_3(\text{SO}_4\text{-Na(Ca)-Mg})$  type water, which is favorable for development and utilization.

3. The Jiaoliao moderate and high-temperature hot spring concentration zone. This includes the Jiaodong Peninsula in Shandong and Liaodong Peninsula in Liaoning and the zone extending north and south from them with a NE-SW strike. This zone contains over 70 hot springs, most of them at 40 to 70° C, and five with temperatures above 80° C including the Tangdonggou (Zhaoyuan), Dongwenquan (Jimo), Qilitang (Wendeng), Xiongyue (Yingkou), and Tanggangzi (Anshan) hot springs. The salt content and chemical components of the hot springs in this zone are related to their distance from the coast. Those near the coast have a high salt content, usually 3 to 10 grams/liter, which is  $\text{Cl-SO}_4(\text{HCO}_3)\text{-Na-Mg(Ca)}$  type or  $\text{Cl-Na}$  type. Those more distant from the coast have lower salt contents of 1 to 3 grams/liter, and the water quality changes to an  $\text{HCO}_3\text{-Cl(SO}_4)\text{-Na(Ca)-Mg}$  type.

4. The Sichuan-Yunnan moderate and low-temperature hot spring concentration zone. This is located in Luding, Shimian, and Xichang in western Sichuan and extends in a north-south direction through Huili to Kunming along the Anning He valley. There are over 80 hot springs here that are rather concentrated, but their temperatures are somewhat low, most from 40 to 50° C, and there are very few hot springs with temperatures higher than 80° C. The latter have only been discovered at Kangding and other locations.

5. The Fenwei-Zhangbei moderate and low-temperature hot spring concentration zone. This includes the Wei He valley, Fen He valley, Datong volcanic region, and Zhangbei Weichang basalt plateau. There are more hot springs and they have higher temperatures, up to 60 to 80° C, along both sides of the Fen He and Wei He valleys, especially at the southern and northern ends of this zone. There are fewer hot springs in the central region and their temperatures range from 40 to 60° C. Most of them have  $\text{HCO}_3\text{-SO}_4\text{-Ca(Na)-Mg}$  water types with salt contents of 1 to 3 grams/liter. There are no hot spring outcrops in the middle of the valleys due to the enormously thick Mesozoic and Cenozoic capping strata, but inferences from temperature logging data from drilling deep wells indicates that most have a temperature gradient above 3° C/100 meters and there are water-bearing salt strata of substantial thickness in the strata, which indicates that the Fen He and Wei He valleys have rather high ground temperatures and contain rich reserves of superior quality hot groundwater resources.

#### B. Geothermal resources in sedimentary basins

To discuss the geothermal resources of basins, we also must understand the geothermal state of the basins. For this

reason, we are providing a table of the ground temperature distribution characteristics for all of China in Table 1 [not reproduced] to enable analysis of the geothermal resources of basins.

China has 11 large and medium-sized sedimentary basins that can be classified into three categories according to the structural properties and geothermal characteristics of the basins (Table 2).

Table 2. Categories of Sedimentary Basins and Their Ground Temperature Characteristics

Category of Sedimentary Basin	Basement Properties	Capping Strata and Periods	Structural Characteristics and Type of Activity	Ground temperature (°C)			Ground temperature gradient (°C/100 meters)	Notes
				1,000 meters	2,000 meters	3,000 meters		
Mesozoic and Cenozoic sedimentary fault-subsidence basins	Blocks composed of Paleozoic carbonate rock, shale, and silicious limestone, and Protozoic crystalline rock	Tertiary, Quaternary, Cretaceous, and Jurassic sandy mudstone and other components, and some basins have Triassic, Permian, and Carboniferous system sandy mudstone and coal system strata	The basement is a graben and horst type structure composed of a series of fractures that underwent intense tectonism during the Mesozoic and Cenozoic in which fault-subsidence basins formed under combined activity and sedimentation conditions, beneath which are concealed ancient buried hills composed of Paleozoic strata	40-45	70-80	90-100	3-4	The Huabei [North China] Basin and Songliao Basin are representative
Mesozoic and Cenozoic sedimentary subsidence basins	Stable blocks composed of Paleozoic clastic rock and carbonate rock and of Protozoic crystalline rock systems	"	Subsidence basins with no obvious basement fracturing activity with stable uplifting activity over a large area that experienced both subsidence and sedimentation. The basins have both uplifts and subsidences, and no intense tectonism during the Mesozoic and Cenozoic	30-40	50-60	70-80	About 2° C/100 meters	The Tarim Basin and Jungar Basins are representative



Table 2. Categories of Sedimentary Basins and Their Ground Temperature Characteristics (Continued)

Category of Sedimentary Basin	Basement Properties	Capping Strata and Periods	Structural Characteristics and Type of Activity	Ground temperature (°C)			Ground temperature gradient (°C/100 meters)	Notes
				1,000 meters	2,000 meters	3,000 meters		
Mesozoic sedimentary subsidence basins	Stable fault blocks composed of Paleozoic carbonate rock and clastic rock and of Proterozoic metamorphic rock and crystalline rock	Mainly composed of Mesozoic Cretaceous system, Jurassic and Triassic system sandy mudstone and saline rock with some Permian system coal system strata	Mounting building activity in the basement after the later part of the Mesozoic caused the formation of broad and gentle anticlines and synclines or uplifts and subsidences in the basins. Tectonism in the basins was weak	35-45	60-70	90-100	2.4-2.9	The Ordos Basin and Sichuan Basin are representative

1. Geothermal resources of Mesozoic and Cenozoic fault-subsidence basins. The thickness of the Mesozoic and Cenozoic sedimentary capping strata in this type of basin can be several 1,000 meters, and the maximum thickness is over 12,000 meters. Most are composed of Quaternary, Tertiary, Cretaceous, and Jurassic strata. Some of the basins have Triassic and Paleozoic Carboniferous-Permian strata. Their lithology is mostly sandstone, mudstone, and powdered sandstone. Some areas have clastic rock, conglomeratic sandstone, and Paleozoic marl. Devonian and Silurian system strata are frequently absent. Their basements are composed of Ordovician, Cambrian, Sinian, and pre-Sinian system limestone, sandy limestone, and sandy shale, metamorphic rock, and so on. Analysis of drilling profiles indicates that the sandstone-mudstone ratio in the Mesozoic strata is about 1:3. The ground temperatures in the basins are 40-45° C at a depth of 1,000 meters, 70-80° C at 2,000 meters, and 90-100° C at 3,000 meters. The highest ground temperatures are found in the Songliao Basin and the second highest in the Huabei Basin. The temperature gradient in the basins is 3-4° C/100 meters and can exceed 7-8° C in certain geothermal anomaly regions. The properties of the water in the heat reservoir strata vary according to basin: in Huabei Basin, the Guantao group is better and the Shahejie group is poorer; the degree of mineralization for the former is about 1-3 grams/liter and it is HCO<sub>3</sub>-Cl-Na-Ca type water. It is more than 30 grams/liter in the latter and it is Cl-HCO<sub>3</sub>-Na-Ca(Mg) type water. The Songliao Basin is mostly in the range of 10 to 30 grams/liter and the water quality is similar to that in Huabei. In the Jiangnan Basin, however, it is greater than 200-300 grams/liter and it is moderate to high-temperature brine which can crystallize and block boring during the process of overflowing and erupting. Which the exception of being

rather poor in Songliao Basin, the water content of the Mesozoic and Cenozoic rock strata preserves rich hot groundwater.

The basement of most of the sedimentary fault-subsidence basins is composed of Ordovician, Cambrian, Jixian, and Qingbaikou system limestone, dolomitic limestone, silicious limestone, and other structures. The effects of Yanshan and Xishan activity increased basement fracturing activity and formed a series of graben and horst structures. There are very large undulations in the basement terrain and it is capped by Mesozoic and Cenozoic strata which formed many concealed mountain ridges and valleys. The rock cavities and sutures which formed the buried hills are the sites of excellent passage and preservation of hot groundwater. These zones are extremely rich in geothermal resources.

The buried hills in the basins are mostly buried at depths of 700 to 2,000 meters. They have temperatures of 70 to 100° C and up, their salt content is mostly 1 to 10 grams/liter, and it is usually Cl-HCO<sub>3</sub>-Na type water. The water flow rate is several 10 to 1,000 m<sup>3</sup>/hour and they are important heat reservoiring strata in the sedimentary fault-subsidence basins. The buried hill geothermal resources have advantages like good quality, large amounts, high temperatures, shallow burial, and so on and they are the primary heat reservoiring strata in the basins that are most conducive to development.

2. Geothermal resources of Mesozoic and Cenozoic sedimentary subsidence basins. These basins have a fault-block basement composed of Paleozoic and Proterozoic strata and crystalline metamorphic rock systems. The basins underwent stable subsidence during the Mesozoic and Cenozoic due to the effects of intense folding and uplifting from mountain building in the surrounding area and they received enormously thick

sediments. The Mesozoic and Cenozoic strata in the basins are generally 2,000 to 5,000 meters thick and some are greater than 7,000 to 8,000 meters. The ratio between the sandstone and mudstone which form these strata is about  $\frac{1}{2}$  to  $\frac{1}{3}$ . With the stable uplifting of the basin basement, the Mesozoic and Cenozoic strata formed uplift and subsidence structures and activity by local fracture structures did not affect the properties of the basins as a whole. As a result, the ground temperatures in basins of this category are somewhat lower, with the ground temperatures in most ranging from 35 to 40° C at depths of 1,000 meters, 50 to 70° C at 2,000 meters, and 70 to 90° C at 3,000 meters. Their ground temperature gradient is about 2° C/100 meters. The salt content of the hot groundwater varies with the depth. It is mostly 10 to 30 grams/liter at 1,000 to 2,000 meters, and is usually  $\text{Cl-HCO}_3(\text{SO}_4)\text{-Na}(\text{Ca})\text{-Mg}(\text{Ca})$  type water. They are geothermal resource distribution regions formed under normal geothermal temperature increases. Hot groundwater at 40 to 70° C with a salt content of 10 to 30 grams/liter can be obtained from depths of 1,000 to 2,000 meters in this category of basins and it can be used for the direct supply of hot water for greenhouses, heating, or heating cold freshwater, especially when the groundwater moves through artesian flow to the surface through drilling and has a relatively low salt content (10 grams/liter) giving it even greater use value. During drilling to a depth of 2,000 meters on the western flank of Bai Shan at Karamay in eastern Junggar Basin, for example, hot water at 70° C flowing in an artesian flow from Carboniferous volcanic rock at a rate of 5,000 m<sup>3</sup>/day had a salt content of about 17 grams/liter, so it had definite development and utilization value.

The capping strata and basements in Mesozoic and Cenozoic sedimentary subsidence basins both reservoir relatively rich geothermal resources, but the salt content is most cases is rather high (up to 100 to 200 grams/liter). As a result, when developing their geothermal resources, attention also should be given to extracting useful chemical components to attain the goal of using one source of energy for multiple purposes.

3. Geothermal resources of Mesozoic sedimentary subsidence basins. The Sichuan Basin and Ordos Basin belong to this category. The basin basements are composed of pre-Sinian metamorphic rock and Paleozoic Permian, Carboniferous, Ordovician, and Cambrian system strata. The Devonian system is usually absent. They are stable fault-block basins. The Mesozoic Triassic system and Cretaceous system strata in the basins are rather thick, while the Quaternary and Tertiary system strata are just a few meters, a few 10 meters, or are even absent. The Mesozoic strata were subjected to the effects of tectonism which formed broad and gentle anticlines and synclines in Sichuan Basin but formed uplifts and subsidences in Ordos Basin. However, the fracturing activity in the basins was not intense and huge deep fractures formed the boundaries between the basins and the folded and uplifted mountainous regions. Because the basins underwent a process of stable

uplifting activity, their ground temperatures are lower than sedimentary fault-subsidence basins. Because the deep structures of the basins and their basements are buried at rather shallow depths, and because of variations in the thermophysical properties of their rock, their ground temperatures are also higher than in Mesozoic and Cenozoic sedimentary subsidence basins. The ground temperatures in the basins are 35 to 45° C at a depth of 1,000 meters, 70 to 80° C at 2,000 meters, and 90 to 110° C at 3,000 meters. The ground temperature gradients are about 2.45 (Sichuan) to 2.9 (Ordos)° C/100 meters. Because of differences in the Mesozoic strata within these two basins, there are significant differences in the salt content and chemical composition of their hot groundwater.

Most of the Mesozoic strata in Ordos Basin are composed of sandstone, mudstone, and conglomeratic sandstone, and there are Jurassic and Carboniferous system coal system strata, but no gypsum-halite, saline rock, or other evaporite strata have been discovered. The salt content of the hot groundwater they contain is mostly 10 to 30 grams/liter and it is  $\text{Cl-HCO}_3(\text{SO}_4)\text{-Na}(\text{Ca})\text{-Ca}(\text{Na,Mg})$  type water.

Sichuan Basin has saline rock and gypsum strata several 10 meters to over 100 meters thick in Jurassic system Xiangxi group and Triassic system Leikoupo group strata, and the other strata also have many saline rock and gypsum strata that are interbedded with dolomitic limestone, limy dolomite, and so on. The Permian system is coal system strata. Thus, the hot groundwater in the pores of the Jurassic system sandstone and mudstone and in the cavities and sutures in Triassic system dolomitic limestone or limestone contains a large salt component that forms the famous Sichuan hot brine that can have a salt content of more than 200 grams/liter that is  $\text{Cl-Na}$  type water, and they contain 10 to 30 grams/liter saline water. The brine and saline water contain trace elements like rubidium, strontium, lithium, iodine, and so on which are important raw materials for well salt. In addition, the hot groundwater in the solution cavities and sutures in other shallow strata and in deep basement Ordovician and Sinian strata have a lower salt content, usually 10 to 50 grams/liter. The lowest is <1 to 3 grams/liter and the highest can exceed 76 grams/liter.

## II. Types of Geothermal Resources

Based on the properties and conditions of heat sources and heat reservoiring, the category of heat-carrying media, and the geological structural characteristics that control the resources and in conjunction with concrete conditions in China, we will now divide geothermal resources into four main categories and five sub-categories (Table 3) [not reproduced]:

### A. Modern volcanic and magmatic geothermal resources

These are divided into two sub-categories based on the properties and characteristics of their heat sources and

heat-carrying media: 1) Modern volcanic region geothermal resources; 2) High-temperature magmatic geothermal resources.

1. Modern volcanic region geothermal resources. The red-hot magma in modern volcanic regions intrudes along sutures or fractures and erupts onto the surface. The high-temperature magma heats the atmospheric precipitation that permeates and is reservoirized in the sutures of the magmatic rock or the pores in sedimentary capping strata and forms high-temperature heat reservoirizing strata. Some of the hot water and steam moves through fractures and pores in the rock and again erupts at the surface forming powerful geothermal indications, most of which have temperatures of more than 100° C. The heat-carrying media of this category of geothermal resources often has chemical components that are differentiated from the magma and which have rather low pH values. The temperature of most of their reservoirized heat is 200 to 300° C. The gradient of the geothermal regions can exceed 10 to 20° C/100 meters. The formation of these resources is related to the magmatic activity of modern active volcanoes or dormant volcanoes. Most of the geothermal resources at Macao and Dahuangzui in Taiwan's Datun volcano cluster, at Tengchong in Yunnan, and other regions belong to this category.

2. High-temperature magmatic geothermal resources. The heat source for these is molten or presently cooling magma or magmatic bodies. There are no obvious geothermal activities in the regions where this type of resources are found, but there are powerful geothermal indications, including the appearance of geysers, boiling springs, and hydrothermal explosions and the temperature of the hot springs is higher than the local boiling point. Inferences from Na-K-Ca temperatures indicate that the temperature of most deep heat reservoirs is 180 to 200° C and the ground temperature gradient is greater than 10 to 15° C/100 meters. The overheated hot groundwater contains B, I, Li, Rb, Sr, and other trace elements related to magmatic differentiation products. Seismic depth sounding indicates the presence of low-velocity strata 2,000 to 3,000 meters and 10,000 to 20,000 meters below ground which may be molten magma or magmatic bodies. This category of resources can be found at locations like Qingshui-Tuchang and Lushan on Taiwan, Yangbajing, Laduogang, Kawuji, and Lugu in Tibet, and other areas.

Modern volcanic and magmatic geothermal resources are mainly found at the contact zones of the plates which form the globe and in some intensely active deep fracture zones. These areas are conducive to the upward movement of mantle materials or heavy molten crustal materials along fracture passageways. This plays an indispensable and important role in the formation of volcanic and magmatic rock type high-temperature geothermal resources.

B. Uplifting and fracturing deep circulating type geothermal resources

Most of the geothermal resources in this category lie along deep fracture zones that are found in uplifted mountainous regions and hilly regions, and the deepest of fractures may extend as deep as the mantle, but generally vary from 2,000 to 10,000 meters. Their properties are mostly tension normal faults or tensile-shear fractures. Because of the historical evolution of the structural activity, changes also occur in the properties of the faults. It is for this reason that uplifting and fracturing deep circulating geothermal resources are still controlled by regional structures, but most of them outcrop as hot springs at the points of intersection between huge structures and local tensile fractures. The heat-carrying media of this category of resources is mainly water, precipitation, and surface water that follows strata to permeate and run off into deeper areas, and it is hot groundwater that is formed by heating with a normal geothermal temperature increase. It flows upward by convection when the terrain and structures are at appropriate positions, and outcrops at the surface or is concealed beneath the ground to form hot springs or hot ground surfaces.

The temperatures of the hot water in this category of resources is determined by the depth of groundwater circulation. It usually does not exceed 100° C at the surface and most is in the 40 to 90° C range, but can exceed 100° C at 1,000 meters below ground, and most of it is moderate and low-temperature geothermal resources. The salt content of the hot water is usually <1 to 3 grams/liter, and it is composed of HCO<sub>3</sub>-SO<sub>4</sub>(Cl)-Na(Ca)-Mg type water. The salt content is higher along coastal areas, however, and can reach 3 to 10 grams/liter, but it changes to Cl-HCO<sub>3</sub>(SO<sub>4</sub>)-Na(Ca)-Mg type water. Its heat reservoirizing strata is rock sutures, fractured and cracked zones, and weathered zones and Quaternary sandy conglomerate strata that cap it above.

This category of geothermal resources is distributed throughout all of China's provinces and autonomous regions, and it is the main type of moderate and low-temperature geothermal resources.

C. Sedimentary fault-subsidence basin type geothermal resources

These are divided into three sub-categories according to their basement structures and the formational characteristics of the resources:

1. Fault-subsidence basin basement convection type geothermal resources. The basement in this category of basins is composed of a series of horst and graben structures formed of Ordovician, Cambrian, Sinian, and pre-Sinian system carbonate rock and ancient crystallized rock and are buried beneath the ground in the form of buried hills. Cavities and sutures have developed in the carbonate rock and there was intense structural activity in the basement which provides excellent conditions for the upward convection of hot groundwater in deep areas along fractures, cavities, and sutures. The top

part is Mesozoic and Cenozoic sandy mudstone traps which form groundwater heat reservoir strata.

The main characteristics of convection-type geothermal resources are: 1) The geothermal temperature increase rate of the underground heat reservoirs is low and the gradient is small; 2) The chemical components and salt contents are relatively identical; 3) Cavities and sutures have developed in the heat reservoirs and there is rather intense fracturing activity, which are conducive to the creation of convection; 4) Obvious ground temperature anomalies (with ground temperature gradients of more than  $4^{\circ}\text{C}/100$  meters, the highest of which can reach  $7$  to  $8^{\circ}\text{C}/100$  meters) often formed on top of the buried hills or on one side of the fractures.

The heat reservoir temperatures of the convection type geothermal resources varies with depth. They are mostly between  $110$  and  $130^{\circ}\text{C}$  at depths of less than  $3,000$  meters and the hot groundwater which flows to the surface through artesian flows via drilling is  $40$  to  $90^{\circ}\text{C}$ , and the highest can exceed  $100^{\circ}\text{C}$ . These hot water resources are replenished by the permeation of precipitation and are heated by geothermal temperature increases, and they are formed by flowing upward along cavities and sutures or fractures to form heat reservoirs at the top of buried hills. The salt content of the hot water is usually  $1$  to  $10$  grams/liter and the highest can reach  $30$  grams/liter. It is  $\text{Cl-HCO}_3\text{-Na-Ca(Mg)}$  type water. The flow rate is rather large, from several  $10\text{ m}^3$  to several  $100\text{ m}^3$  per hour. The primary geothermal resources now being exploited in Huabei Basin belong to this category.

2. Sedimentary fault-subsidence basin basement uplift type geothermal resources. This category of resources is mainly formed by uplifts of carbonate rock or other types of rock with rather good heat conduction properties. Because of the excellent conducting properties of the basement rock, heat from the mantle collects at the top of the uplifts and the groundwater in the heated basement and its upper strata form geothermal anomalies. There is an obvious increase in the temperature gradient with depth and the chemical components change along with it, while there are fewer cavities and sutures in the fractures and heat reservoirs as the depth increases, indicating that the convection conditions of the hot

groundwater are rather poor. Most of the hot groundwater in the Tertiary Guantao and Minghuazhen group heat reservoir strata in Huabei Basin belongs to this category.

3. Ground pressure type geothermal resources. The rapid subsidence of fault-subsidence basins accumulated enormously thick Mesozoic and Cenozoic strata ( $3,000$  to  $8,000$  meters and up) and underdensified strata exist in deep areas, including some that contain large amounts of hot groundwater, dissolved hydrocarbons, and flammable methane gas, and they have highly anomalous strata pressures and temperature gradients. The temperature of the heat they reservoir is above  $100^{\circ}\text{C}$ . This type of geothermal resources may exist in some large fault-subsidence basins in east China. Research has led to the discovery of underdensified strata with highly anomalous pressures at depths of  $3,000$  to  $4,000$  meters in the area of Huabei Basin and the Bohai Bay. This provides important information for the search for ground pressure type geothermal resources.

#### IV. Sedimentary Subsidence Basin Type Geothermal Resources

Sedimentary subsidence basins have stable ancient crystalline rock system basements. During the process of stable subsidence, they received enormously thick Paleozoic, Mesozoic, and Cenozoic sediments including buried groundwater and groundwater formed by the mixing of precipitation with surface water. The water formed in these two ways was heated with depth by heat conduction and formed heat reservoir strata in the basins. Their temperatures are determined by the depth of burial of the heat reservoirs. The temperature of most of the resources in this category is about  $100^{\circ}\text{C}$  at a depth of  $3,000$  meters while the temperature of most of the hot groundwater that flows out in artesian flows through drilling is  $40$  to  $70^{\circ}\text{C}$ . The salt content of the water depends on the conditions of the heat reservoir strata. The salt content of trapped underground brine can be  $100$  to  $200$  grams/liter and higher and it is  $\text{Cl(SO}_4\text{)-Na(Mg)-Ca}$  type water. It can be  $1$  to  $30$  grams/liter in heat reservoir strata with better underground runoff conditions and it is  $\text{Cl(HCO}_3\text{)-SO}_4\text{(Cl)-Na(Ca)-Mg}$  type water.

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